PREPARING FOR PUBLICATION

THE BOOK OF FARM-BUILDINGS

THEIR ARRANGEMENT AND CONSTRUCTION

BY

HENRY STEPHENS, F.R.S.E.

AUTHOR OF THE "BOOK OF THE FARM"

AND

ROBERT SCOTT BURN

ENGINEER

In One Volume, Royal Octavo, uniform with the "Book of the Farm," and the "Book of Farm Implements and Machines"

ILLUSTRATED WITH NUMEROUS PLATES & WOOD ENGRAVINGS

THE object of this Work is to indicate, in the most distinct manner, that arrangement of the Apartments in Farm-Steadings best adapted for each of the methods of Farming practised in the kingdom. It may surprise those unacquainted with Agriculture to learn that there are various modes of Farming. There are not fewer than Five distinct systems of Farming pursued in this country. In view, then, of this variety in modes of practice, it will be obvious that no single arrangement, however apparently complete and well conceived, can meet the requirements of all circumstances of practice, or be calculated to secure the strictest economy of labour. As the manufactures of wool, cotton, silk, or flax, require arrangements of premises suited to the peculiarities of the material to be operated upon, so in like manner do the peculiarities of "dairy," "pastoral," or of "mixed" husbandry, demand arrangements calculated to aid their practice. A very slight consideration indeed of this subject will suffice to show that the accommodation required on a farm solely devoted to the rearing of live-stock, should not be the same as that required for one which is cultivated entirely for the raising of corn.

But although the arrangement of the Apartments of Steadings should vary in accordance with the kind of Farming, yet every arrangement suited to the various modes of Farming may be founded upon such a General Principle as shall insure the greatest convenience and economy in the use of each arrangement.

The Authors are quite aware of the difficult task they have undertaken in order to attain the important object they have thus enunciated; but, nevertheless, they flatter themselves that the object has been attained in this Work, and that for the first time by any writer who has hitherto attempted to illustrate Farm-Buildings.

Without pledging themselves to any specific amount of matter, the Authors may be permitted the statement that, in addition to Plans expressly prepared to working scale, to elucidate the "Principle" of arrangement of Steadings suited to all varieties of Farming, and to ample working details of construction and fittings of apartments, it is proposed to give such Plans of Farm-Houses, and of Bailiffs' and Labourers' Cottages, as shall exhibit details of convenient arrangements and fittings. The construction of Bridges, Embankments, Culverts, Dams, &c.—those "outlying buildings" of the Farm—will also receive due attention. It is thus the aim of the Authors to make the work a trustworthy and practically useful authority in all matters connected with the Buildings of the Farm.

WILLIAM BLACKWOOD AND SONS
EDINBURGH AND LONDON

THE BOOK

OF

FARM IMPLEMENTS AND MACHINES

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BY

JAMES SLIGHT AND R. SCOTT BURN

ENGINEERS

EDITED BY

HENRY STEPHENS, F.R.S.E.

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MDCCCLVIII

PREFACE.

By the time a Second Edition of the *Book of the Farm* was demanded, a great prospective advance in theoretical agriculture was propounded by chemists, at the head of whom stood the eminent Liebig. The proposition was to explain the *rationale* of agricultural practice on scientific principles, and to establish it for the future upon a foundation of true philosophy, instead of the empiricism by which it had hitherto been upheld. Like every new and unexpected proposal, the aid of chemistry to agriculture, promising such great results, excited ardent expectations, and was hailed with particular favour by agriculturists at a period when their interests were likely to be injured by foreign competition; and although, after some experience, the results have, unfortunately, not been so decidedly beneficial as was at first anticipated, enough has been demonstrated by the returns of the field to convince the agricultural community that their art, in order to reach its utmost importance, must, for the time to come, be based upon the suggestions of chemistry. At once many of the practical results of farming were satisfactorily explained by the action of chemical laws, while the composition of vegetable and animal products was soon made known to the farmer, as were also the direct effects of special substances upon growing crops and fattening animals, so that a large number of valuable facts were speedily collected as data for future guidance in practice. In any work on systematic agriculture, those accumulated facts could not be overlooked without culpable neglect. This being the state of matters when the Second Edition of the *Book of the Farm* was in hands, it was found necessary to rewrite the theoretical portion of that work; and as the adoption of new matter would have much enlarged its bulk, which was large enough already, it was determined rather to diminish it by excising the parts which described minutely the construction of agricultural machines. In following out this plan, it was the intention of the late Mr Slight, by whom the descriptions referred to had been written, to have described the mechanical construction of every important machine and implement in use, and to have published his descriptions in a separate work, as a companion to the Second Edition of the *Book of the Farm;* but death put an end to the scheme, and deprived, at the same time, agricultural mechanics of one of its most clear-headed and successful expositors. Years passed by without the prospect of the completion of the contemplated work, until the Editor became acquainted with Mr Robert Scott Burn, a young and enthusiastic practical engineer, who had devoted a considerable portion of his attention to agricultural mechanics. With his assistance, this work has been at length completed.

Seeing that many of our agricultural machinists displayed in their works deficiency in mechanical science, and, in consequence, mechanical construction, it was deemed expedient, in order to render this work specially useful to them, to dwell somewhat fully on those branches of mechanical science which bear most obviously on their particular art, and to illustrate the principles upon which it is founded, by the selection of the most useful machines and implements that exhibit greatest talent in mechanical construction. For this purpose much of the matter contributed by Mr Slight has been made use of, while many machines which have been brought into practice since his day are now described by Mr Burn with due mechanical minuteness for the first time. It is evidently impossible to figure and describe every agricultural machine in use in these Islands, nor is such a task necessary to be undertaken. It suffices, on taking a general survey of the vast number of agricultural machines which have been presented to the notice of agriculturists, to select only those which are really of use. The whole stock of agricultural machines may be divided into two categories,—namely, those which are not now in general use, and those which are in use. It is needless to describe machines which have become obsolete, only those which are in use really deserving our attention; and even every one of these should not be described, because some cannot be commended, and others are inaccessible on account of the indifference or jealousy of their inventors. It is painful to advert to this last circumstance, but it is incumbent on us so to do, in order to the explanation of our apparent neglect in overlooking what may by many machinists be deemed good and useful machines, and which would most probably have been figured and described had their inventors and makers willed that it should be so. We, however, avail ourselves with pleasure of this opportunity to acknowledge our special obligations to the following firms and gentlemen, for affording us information in connection with the several machines and implements, for the invention and manufacture of which they are celebrated : Messrs Garrett, of Saxmundham, Suffolk ; Messrs Clayton and Shuttleworth of Lincoln ; Messrs Ransome and Sims, Ipswich ; Messrs Hornsby, Grantham ; Messrs Richmond and Chandler, Manchester ; Messrs Barrett, Exall, and Andrewes, Reading ; Messrs Rankin, Liverpool ; Messrs Dray and Co., London ; Messrs Tuxford, Boston ; Messrs Smith and Ashby, Stamford ; Messrs Reeves, Westbury ; Messrs Williamson, Kendal ; Messrs Turner, Ipswich ; Messrs Gwynne, London ; Messrs Griffith, Birmingham ; Mr Fowler, London ; Mr B. Samuelson, Banbury ; Mr Bentall, Heybridge, Maldon ; Mr Thompson, Lewes ; Mr Coleman, Chelmsford.

Confining our consideration to machines and implements actually in use in agriculture, we have divided them according to the two great purposes for which they were invented—namely, into those used directly in the cultivation of the soil, and those used only in connection with its products. In treating of their mechanical construction, it was necessary to test the applicability of each machine to the purpose for which it had been invented ; for unless this can be established by proper criteria, no progress can be claimed, for agricultural machinery, towards such perfection as is to be found in machines in the other arts to which the industry of the nation is directed. To attain this desirable end, it is a prominent feature of this work, in the first place, to elucidate the scientific principles which regulate the choice of materials in the construction of machines and implements ; and, in the next place, to illustrate the practical construction and properties of those machines and implements, and their adaptation to the particular purpose for which they are employed in agriculture.

Although, as we have already said, it is impossible to notice every machine in use, yet we are not unaware of the advance towards perfection which is being made in every department of agricultural mechanics. Of the modifications and peculiarities of numerous recent inventions in agricultural mechanism, and of the practical results of the working of many of them, we have had full information ; but the limits of this work, in addition to the reason above referred to, have precluded their being noticed. Of these inventions and their inventors we may here mention—

In Steam Cultivation.—Mr William Smith of Woolstone, Bucks ; Mr John Allin Williams of Balyden, Wilts ; and Mr P. A. Halkett of Merton Road, Wandsworth, London. These gentlemen, by a large expenditure of time and money, have done much towards the solution of the question of economical steam-cultivation. The inventions of Mr Smith and Mr Williams depend for their action on a system of traction by ropes, pulleys, and windlasses, after the manner, more or less modified, employed by Mr Fowler, whose plan we have fully described. Mr Halkett's plan involves arrangements of decided novelty, inasmuch as he prepares the land to be cultivated for the operation of the implements employed, by laying down tram or guide ways, by which he proposes to insure a precision of operation otherwise unattainable. Of machines or implements adapted to steam-cultivation, to be dragged over the land either by the direct power of a portable steam-engine fitted with Boydell's Endless Railway, or by the windlass-and-pulley system of Fowler, and cognate plans, we may here notice the Cultivator, with revolving tines, of Mr Bernard Samuelson of Banbury, and the Eleven-tined Cultivator of Mr Richard Coleman of Chelmsford. Of recent patents connected with steam-cultivation now attracting attention, mention may be made of those of Mr A. Dacre Lacy, of Hall House, Knayton, near Thirsk, Yorkshire ; of Mr Thomas Keddy, of Handsforth, Stafford ; of Mr T. Ricketts, of Castle Foundry, Buckingham ; and of Messrs Howard and Baker, Bedford.

In Hay-making and Corn-reaping Machines.—The Self-acting Horse-rake of Messrs Marychurch and Son, Haverfordwest ; and the American Eagle Mowing-Machine, of Nourse, Mason, and Co., of

Boston, U.S. (European Agent, H. S. Olcott, 31 Essex Street, Strand); the Improved Reaping-Machine of Mr George Bell of Inchmichael, Errol, by Perth; and the Union Reaping-Machine of Mr John Palmer of Stockton-on-Tees.

In Thrashing and Corn-dressing Machines.—The Thrashing-Machine of Messrs Barrett, Exall, and Andrewes, with wrought-iron beater; the Adjustable Corn-dressing Screen of Mr Roby; the Patent Hummeller of Messrs Barnard and Bishop, Norwich; and we have very recently had an opportunity of seeing in operation the simple Corn-cleaning Apparatus, attached to the Thrashing-Machine, invented by Mr Robert Hislop, junior, Prestonpans, near Edinburgh.

In Miscellaneous Inventions, the Draw-share Hoe of "Sigma," and the Straw-Rope Spinner of Mr Thomas Simpson of Petersham, Surrey.

To those desirous of studying minutely the peculiarities of the different varieties of English agricultural machines and implements, we would recommend a visit to be paid to the "Department of Agricultural Machinery" in the Crystal Palace at Sydenham. The collection comprises specimens of the manufactures of the most eminent makers, and requires only a few additional examples, and a system of classification, to make it complete. As it is, the comparatively good arrangement, and the facilities offered by the Company for a quiet inspection of its contents, render a visit to the collection a much more likely method of obtaining sound information, as to details of construction and peculiarities of arrangement, than a hurried inspection of the machines and implements which a crowded agricultural show affords. It is to be regretted that the agricultural-implement-makers of Scotland do not avail themselves of the favourable opportunity of exhibiting their handiworks alongside those of their English brethren: they need not fear competition, either in workmanship or cost.

In the preparation of many of the drawings, we have to express our obligations to Mr G. H. Slight, well known as an able draughtsman; to Mr C. E. Johnson, a rising artist; and to Mr J. Hunt.

In the elucidation of the *principles of construction,* we have necessarily been confined to a mere outline or abstract. The reader desirous of extending his knowledge, may consult with advantage the following works:—

"Moseley's Engineering and Architecture," 2d ed.: Longmans, 24s. "On the Application of Cast and Wrought Iron to Building Purposes," by William Fairbairn; 2d ed.: Weale, 12s. "Useful Information for Engineers," by William Fairbairn, 10s. 6d. "Water Wheels and Buckets," by William Fairbairn, 7s. 6d. "Report of the Commissioners appointed to inquire into the Application of Iron to Railway Structures," 30s. "Report on the Fall of a Cotton Mill at Oldham" (Mr Fairbairn and Mr Hodgkinson's evidence particularly), 3s. 6d. Articles *Iron* and *Carpentry*, in the "Encyclopædia Britannica." "Encyclopædia of Civil Engineering," by Edward Cresy: Longmans, new edition, 63s. "Tredgold's Carpentry," 42s. "The Builder's Practical Directory:" Ainsworth, Manchester, 47s. "The Practical Draughtsman's Book of Industrial Design, being a complete Course of Mechanical Engineering and Architectural Drawing," by Wm. Johnson: Longmans, 26s. "Weale's Engineer's Pocket-Book," 6s. "Adcock's Engineer's Pocket-Book:" Simpkin, Marshall, & Co., 6s. "Templeton's Millwright's and Engineer's Companion." "Templeton's Workshop Companion." "Bourne on the Steam-engine:" Longmans, 27s. "Bourne's Catechism on the Steam-engine:" Longmans, 6s. "The Working of the Steam-engine explained by the Indicator," by J. Hopkinson, 7s. 6d. "The Steam-engine," 2s., and "Practical Mechanics," 1s. 6d., by J. Imray: both of these form part of the "Circle of the Sciences," published by Houlston & Wright. Eight volumes of the Rudimentary Series, published by Weale of London: 1. "Steam Boilers," by G. Armstrong, 1s.; 2. "The Power of Water," by T. Glynn, F.R.S., 1s.; 3. "Steam-engine," by Dr Lardner, 1s.; 4. "Art of Constructing Cranes," by T. Glynn, F.R.S., 1s.; 5. "Tubular and Girder Bridges," 1s.; 6. "Mechanics, and Practical Construction of Machines," by J. Baker, 2s.; 7. "Foundations and Concrete Works," by E. Dobson, 1s.; 8. "Limes, Cements, and Mortars," 1s. "The Modern Practice of Boiler Engineering," by Robert Armstrong, C.E., revised by John Bourne, C.E.: London, Spon & Co., Bucklersbury, 2s. "Three Reports on the Use of Steam-Coals of the Hartley District, Northumberland," by W. G. Armstrong, C.E., J. A. Longridge, C.E., and Dr Richardson: London, Weale; Newcastle, A. Reid, 1s. The last of these works contains, in small space, a variety of practically useful hints and suggestions on the management of boiler-furnaces, and the consumption or prevention of smoke therein. An analysis also will be found in it of the Government Report on Fuel by Dr Playfair, to which we have referred in the text.

To the reader desirous of following out to a fuller extent the elucidation of the principles of the subjects of which they treat, we have every confidence in recommending the above works, as abounding in matter of high value, both theoretical and practical. To several of these, in the preparation of the text, the Authors have been under special obligations.

HENRY STEPHENS.

REDBRAE COTTAGE, EDINBURGH,
15*th July* 1858.

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ERRATA.

In par. 304, p. 69, *for* "we deduced," *read* "are deduced."

In title of cut, fig. 3, p. 3, *for* "strength of beams in their depth," *read* "strength of beams as their depth."

Par. 872, p. 246, omit.

After par. 1119, p. 327, *read* par. 872, p. 246.

In title to fig. 161, p. 92, *for* "horizontal," *read* "longitudinal vertical."

In par. 1592, *for* "washer-churn," *read* "dasher-churn."

In title to fig. 712, p. 525, *for* "Gauze," *read* "Gauge."

At p. 572, par. 1973, *for* "by Messrs Gordon," &c., *read* "by Messrs Emerson, late Messrs Gordon and Co., Engineers, of Stockport."

THE BOOK

OF

FARM IMPLEMENTS AND MACHINES.

BOOK FIRST.—PRINCIPLES.

DISSERTATIONS ELUCIDATING THE SCIENTIFIC PRINCIPLES WHICH REGULATE THE CHOICE OF MATERIALS AND CONSTRUCTION OF THE MACHINES AND IMPLEMENTS, AND THE STRUCTURES CONNECTED WITH THEM, ON THE FARM.

1. To the farmer who is to use, and to the mechanic who is to construct, the varied machines, implements, and structures required in the processes of modern husbandry, the importance of a knowledge of the principles which regulate the construction and arrangement of their component parts cannot be over-estimated. We are not forgetful of the fact, that many who pride themselves on being practical men, view with considerable distrust the advances of theory, and hold that greater progress has been made by practice in the field or the workshop than by all the indications of theory.

2. That this knowledge, however, of mechanical principles has a high pecuniary value to the farmer and mechanic, we hope will be made clear by the following considerations.

3. In many instances, cumbrous strength is given to parts which a knowledge of the strains to which they were subjected, and the pressure which they were calculated to bear, would have at once shown to have been unnecessary. Take, for instance, the arrangement of a piece of framework—as a roof, or a gate, or the framing of a machine. A workman ignorant of the strains or pressures to which the materials he employs is subject, and of the methods by which the direction and amount of these strains or pressures are ascertained, uses a heavy part to perform an office which a much lighter one would have effected.

4. Again, a mechanic desirous to make a beam or shaft to do double the work, or to sustain twice the pressure, of a given pattern or model, would naturally double the dimensions, unaware of the fact that he would thus obtain a much greater strength than he anticipated. A knowledge of the law that the transverse strength of square beams of equal length is as the cube of

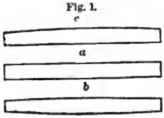
their depth; of rectangular beams, as the square of their depth, multiplied by their breadth, and divided by their length; and of round beams, as the cube of their diameter, would have enabled him to have avoided this mistake.

5. Again, a workman ignorant of the increase of area with increase of diameter, in desiring to make a pipe to convey twice as much water as another given pipe, would be apt to make the new pipe twice the diameter of the given one, finding, as a somewhat unexpected result, that the area of the pipe would be four times that of the model, instead of twice, as anticipated.

6. We see exemplifications of this ignorance of mechanical principles every day around us, and this in connection with even the simplest parts of implements. Thus, the handles of a hay-fork and of a turnip-hoe will be made exactly of the same form, although the strain to which the two implements are subjected is differently situated. Again, we find that instruments of the same class have differently formed handles—one specimen tapering from the working part outwards, another with its taper the reverse of this. Both cannot be right; and a brief consideration of the strain to which the instrument is subjected, would at once show the part which required to be made strongest, and that which had to be made lightest.

7. The same remark applies to beams or parts of implements which have to sustain cross-pressures. A mechanic uninitiated in the principles which denote the best form of beams under such circumstances, would naturally make a beam of the same size throughout, as *a*, fig. 1; while a knowledge of them would enable him to obtain a much lighter, and, at the same time, an equally strong beam, by giving it a certain amount of taper—proceeding from the centre to the extremities, as in the case of the rungs or rounds of ladders *b*, and of swing-trees or whipple-trees *c*, or as in the teeth of hay-rakes.

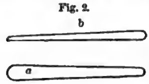
Fig. 1.



RIGHT AND WRONG FORM OF BEAMS

8. Even in the construction of so simple an instrument as the *flail*, the importance of a knowledge of mechanical principles, and of *the habit of investigating the effect* of any proposed form or arrangement of parts, is exemplified. In forming this instrument, a very general practice prevails, which is to have the beater club-shaped, or thickest at the extremity, as at *a* in fig. 2, intended, no doubt, to give better effect to the blows. If we trace, however, the effects of this arrangement, we see that the additional weight is not only unnecessary, but lessens the general effect of the instrument. When every point in the length of the beater strikes the floor with an equal amount of momentum or force, the greatest amount of useful effect will be obtained. In a beater of uniform shape, there will be a constant tendency to a larger amount of momentum at the outer point or extremity—arising from its greater velocity during the gyration of the instrument as compared with the other parts of its length. Now if the extremity be made heavier, this tendency will be augmented, the greater velocity being increased by the greater weight—an undue preponderance will therefore be given to the end of the beater, thereby lessening the general effect upon the work under performance. These considerations point to the flail with the outer extremity of its beater thinner than the other parts of it, as being the form more consonant with the laws of dynamics, as *b*, fig. 2.

Fig. 2.

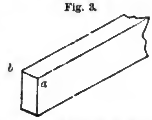


RIGHT AND WRONG FORM OF FLAILS.

9. Again, an ignorance of the effects induced by the mere change of position in a beam or piece of timber, leads often to unexpected results, and to a great

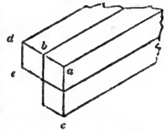
waste of material. Thus a knowledge of the law that, in fixed beams of equal length and same material, the strength increases *directly* as their breadth or thickness, *a b*, fig. 3, and as the *square* of their width or depth, *a c*, fig. 4, will at once show to the mechanic that a beam is much stronger if laid on its edge than if flat. Thus, if a beam of any given length, and 4 inches square, will carry 10 cwt., another beam of the same materials and length, 4 inches broad, *a b*, fig. 4, and 8 inches, *a c*, deep, will have an increase of strength in the proportion of 4^2 to 8^2, or 16 to 64, being four times stronger than the first, or capable of bearing 40 cwt. But supposing the thickness or breadth, *a b*, fig. 4, of the beam to have been doubled to *a d*, while its width or depth, *d e*, remained the same, the strength would only be doubled. From this will be seen the utility of making beams to support a cross resistance narrow and deep, as in the case of a joist, and also the reason for applying the strain to a whipple or swing-tree in the direction of its breadth, or edge-on; and moreover, how great a waste of material would be incurred, without corresponding advantages, by increasing *all* the dimensions of those parts.

Fig. 3.



STRENGTH OF BEAMS IN THEIR DEPTH.

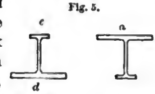
Fig. 4.



STRONGEST AND WEAKEST BEAMS.

10. Take again the use of cast-iron beams with flanges as used in buildings and in the framing of machines. Few comparatively of our mechanics are acquainted with the fact, that if the broad flange, *a*, fig. 5, is placed upwards, it will break with a weight a little more than one-third of that which it will sustain when placed with the flange downwards, as *d*. Still fewer are acquainted with the fact, that the strength of a beam, as *c d*, is nearly a proportional of one section of the *bottom* rib or flange, *d*—that is, that a flange of double the size will give nearly double the strength.

Fig. 5.



STRONGEST AND WEAKEST POSITION OF CAST-IRON BEAMS.

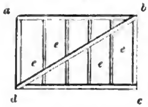
11. It will be of some utility to extend such considerations as those, affording, as we trust they will, suggestions of practical utility. "Of all simple geometrical figures," says Dr Moseley, "the triangle is the only one which cannot alter its form without at the same time altering the dimensions of its sides, and which cannot therefore yield, except by separating at its angles, or tearing its sides asunder. Hence, therefore, a triangle whose joints cannot separate, and whose sides are of sufficient strength, is perfectly rigid. And this can be asserted of no other plane figure whatever. Thus a parallelogram may have sides of infinite strength, and no force may be sufficient to tear its joints asunder, and yet it may be made to alter its form by the action of the slightest force impressed upon it. And this is true, in greater or less degree, of all other four-sided figures and polygons." But the practical utility of these deductions may yet be obscure to the thoroughly practical man. "It is for these reasons," continues the author we have quoted, "that, in all framing, care is taken to combine all the parts as far as possible in triangles, which, being once done, we know that the rigidity of the system may be insured by giving the requisite strength to the timbers and joints."*

12. This practical deduction from the mathematical enunciation just given is of the highest importance in mechanical construction. Let us exemplify it in connection with field-gates—a part of our agricultural economy—than which

* MOSELEY'S *Mechanics applied to the Arts*, p. 132.

none points out so broadly the ignorance of our artisans in those important branches of their education—the elementary truths of geometry and mechanics. A field-gate may be described as a rectangular frame, *a b c d*, fig. 6. No matter what may be the strength of its parts or the extent of its upfillings, *e e*, *e e*, if they are placed at right angles to each other; it is, as we have shown, a very weak form, and liable to change with comparatively slight pressure; but a gate in the form of a triangle would, if the joints and the materials were strong enough, be perfectly immutable. This, however, would be an unserviceable shape; how, then, can the principle of the triangle be applied? Simply thus —if we take a rectangular frame, *a b c d*, fig. 6, so essential to a field-gate, and apply a bar in the position of the diagonal of the parallelogram *b d*, we immediately convert the original rectangular figure into two triangles, applied to each other by their hypotheneuse, and which give us the true elements of a properly constructed gate, all the other parts being subordinate to these, and adapted solely to the practical purposes of the gate as a defence, or for ornament.

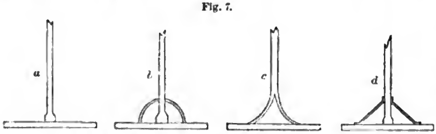
Fig. 6.



FORM OF RIGID STRENGTH.

13. Nor is the proposition of less importance in the minor constructions of the farm; even in such a simple matter as forming a firm connection between the head and the handle of a hay-rake, for its great utility is observable. As many are aware, the simplest method adopted for this purpose is to insert the extremity of the shaft or helve in the centre of the head by a simple tenon, as at *a*, fig 7. Little consideration is required to show the weakness of this plan. To overcome its defects, the extremity of the shaft is sometimes split up for a considerable distance, and the two parts extended, and tenoned into mortices on each side of the central point of the head, as *c*. This is a better arrangement than the first named, but still defective from the concave curve assumed by the forked extremities of the helve. Some mechanics adopt the converse of this plan, and pass a convex or semicircular bow of wood through a slot made near the extremity of the helve, and fasten the extremities of the bow in the head of the rake, as at *b*. This arrangement is even worse than the last one described, inasmuch as the curved bow—weak from its very form—passing through a hole in the shaft weakens this part considerably. The arrangement is slightly modified by other mechanics, who make the bow of iron and nail it to the outside of the shaft. This is better in degree, but still defective in principle. A mechanic, however, acquainted with the principle of stability we have already pointed out, would know at once that the best method to secure a firm connection between the helve and the head of a hay-rake would be by fixing two pieces of perfectly straight light iron rod at one end to the sides of the helve by screw-nails, and at the other by the same means to the head of the rake, at a point equidistant from its centre, as at *d*. This part is called the stay or brace, and in the last-described form is as perfect as the case will admit of.

Fig. 7.



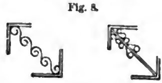
FAULTY METHODS OF CONNECTING THE HANDLE AND HEAD OF A HAY-RAKE. CORRECT METHOD

14. To have said so much of two such simple matters as the construction of a field-gate and a hay-rake may appear trifling, but we have done so in order to

point out the importance of the principle on which depends the strengthening and supporting of the parts of any form of framework, whether of wood or iron, by the aid of diagonal stays or braces. This single member in all constructions is of such importance, that no opportunity should be lost in impressing the principle on the mind of all whose business or interest lies in those departments of mechanics where its application is required. It is no exaggeration to affirm that the knowledge of this principle alone would have effected a large saving of material in many extensive farms. It is somewhat curious to trace in many of the works of agricultural mechanics the incipient knowledge of the usefulness of this principle of stability in the attempts to avail themselves of the diagonal bar. In these we see it applied—with that uncertainty of purpose marking a doubtful and hesitating knowledge of the subject—in all possible positions save the true one, namely—extending from an angle to its opposite.

15. While on this subject it may be useful to point out a common error in the application of stays, as exemplified in the curved bow in the hay-rake *b*, fig. 7, just described. All deviations from the straight line weaken the part so applied, and all extra material necessitated by the use of curves, does not, as supposed by some, strengthen the parts, so used, by adding to the weight, but, on the contrary, weakens it. If ornament is used, it should be added to the diagonal brace or stay, which should always be in a *straight* line, as in the right of fig. 8.

Fig. 8.



FALSE AND TRUE ORNAMENTED DIAGONALS.

16. We have already adverted to the importance of a knowledge of the strains to which different constructive materials are subjected, and the pressures which they are calculated to bear. One wedded to the *practical* notion would be apt to conceive that little utility would arise from the elaborate and minutely tabulated experiments which theorists and purely scientific men have instituted, in order to ascertain these strains and pressures. But irrespective of other advantages, which we shall notice hereafter, the axiom of universal application in mechanical construction, "tie with iron and strut with wood," which has been deduced from them, would have given these experiments a high pecuniary value to the practical man. An ignorance on his part of this axiom has frequently resulted, as we have already said, in a great waste of material, by using heavy and costly parts, which lighter and cheaper would have effected.

17. Let us here investigate this matter briefly, as exemplified in the construction of a gate. In field-gates constructed entirely of wood, the diagonal should invariably be applied as a strut; that is to say, it should *rise* from the *foot* of the heel-post, and terminate at the *top* of the head-post. Placed in this position, the diagonal supports the head or swinging end of the gate, by its resistance to compression—a duty which, from the *area* of its cross section being considerable, and hence capable of resisting lateral flexure, it is well adapted to perform; while, at the same time, the above sectional property gives it a broad terminal resistance, where it abuts upon the angles of the external frame. The same diagonal bar, if applied in the opposite position, and performing the duty of a tie or stay, its great sectional area would avail but little; for, though woody fibre is capable of resisting very considerable tension—larch-wood having, with equal sectional areas, a power of resistance to tension to about $\frac{1}{6}$ that of malleable iron of medium quality—and though this wooden tie might be found to possess, in its aggregate section, a cohesive force greatly beyond that of an iron bar applied in the same position—for the wooden bar would have a sectional area at least twelve times greater than could be requisite for an iron tie, thus yielding an aggregate force double of the iron—yet as the wooden *tie* must

depend for its connection in the structure upon nails or bolts only, its ultimate power of resistance to tension depends not on its own sectional area, but on that of the nails or bolts by which it is fastened, and these, again, may be very greatly reduced by the rending of the extremities of the wooden tie.

18. The advantages of iron as a tie, and its disadvantages as a strut, are just the converse of the foregoing. From the smallness of sectional area requisite in an iron bar applied in this construction, as compared with its length, it is not capable of withstanding compression even to the smallest extent without suffering lateral flexure, and this defect unfits it entirely for the purpose of a strut. Applied as a tie, the iron bar is perfect; the cohesion is such, that a very small sectional area is sufficient for the purpose under consideration: thus, a rod of $\frac{1}{2}$-inch square, even of inferior iron, will bear a tension with safety, of two or three tons, while the best quality will bear six tons; a rod of half this sectional area may, therefore, be held as sufficient for the diagonal *tie* of a gate, and as it can be fixed by bolts without risk of fracturing its ends, as in the case of wood, its application in principle becomes as perfect as it is possible to approach. But though this construction is in principle completely supported by the *tie* from any force tending to depress the head-post of the gate, there is yet a defect in practice; for a gate is liable, from various causes, to be forced upward at the head-post. We have seen that a slender and flexible iron rod cannot resist compression without flexure, and, therefore, a gate with only one iron diagonal tie will still be practically imperfect, and it becomes necessary to apply an antagonist, placed in the position of a strut, but virtually performing the duties of a *tie*, arising from the antagonistic effects of the two, the tendency of the one being to hold the head of the gate up, while the other exerts an equal force to keep it down, whereby a perfect equilibrium is preserved within the structure.

19. It is clear, however, that valuable as this mechanical maxim is—"tie with iron and strut with wood"—something more must be known by the practical man before he can avail himself of it. For however obvious in some constructions the parts are which act as *ties*, and those which act as *struts*, on the other hand there are some constructions in which an inexperienced mechanic would have some difficulty to distinguish the one from the other.

20. Hence arises the utility of a knowledge of the mechanical principles of Carpentry or Framework, and which further enables the direction and amount of pressure exercised upon the various parts of a framework to be ascertained. The *direction* of the pressure pointing out to him the parts which will have to sustain the pressure, and the *amount* giving him an idea as to the size of the part required to sustain the weight or pressure laid upon it.

21. Useful as are the principles of the Mechanics of *Statics*, or those which regulate the construction of parts requiring *stability*, no less useful are those of the Mechanics of *Dynamics*, which regulate the construction and operation of those parts of machines and implements which have *motion*.

22. Take, for example, the construction of shafts or axles with journals. To a workman ignorant of the laws of friction—or at least of the results of well-arranged experiments in connection with them—for of friction, its real nature, we know but little—it would seem a light matter whether the rubbing surfaces were smooth or rough, or whether the journals revolved in metal or material of the same nature—that is, iron upon iron, wrought-iron upon wrought-iron, or cast-iron upon cast-iron. On the other hand, the workman acquainted with these experiments would know that the most refined mode of finishing the surface of the bearings, the most accurate circular form which can be obtained

by turning, and the use of bearings of a different material from that of the shaft, were the best adapted to destroy friction.

23. Again, although the fact is very widely known that the interposition of a lubricating substance between rubbing surfaces tends to reduce the friction, little may be known of the different effects of different substances, and how friction is increased by one unguent, while it is lessened by another.

24. By attention to these points, and to the proper construction of the bushes or bearings, not only may a saving of lubricating substance be effected in a short time, sufficient to repay the additional cost of the improved fittings, but the working capability of a machine may be considerably increased.

25. In the construction and arrangement of other parts of machines—as in the use of fly-wheels; the determination of the best form to give to the teeth of wheels to insure freedom and uniformity of motion and to avoid all unnecessary shocks and strains; to determine the dimensions of the various parts—avoiding undue strength, which will only add to the power expended on the one hand, and give undue weakness on the other, so as the strength of all the parts may be in a proper ratio to the strains to which they are subjected—the utility of correct indications of theory will be as obvious, as we trust we have already shown them to be, in connection with the other departments of mechanics noticed.

26. It would be an easy matter here to extend our remarks illustrative of the loss of material and consequent loss of labour incurred by a neglect or ignorance of correct mechanical principles, but such extension we do not deem necessary. It must be obvious, we think, that want of attention to these mechanical principles must add to the original cost of a machine or implement, by unnecessarily increasing its weight, or the number of its component parts, and, in addition, be a source of perpetual loss so long as it is employed, by the extra labour incurred in using it. The propriety of preceding our chapters descriptive of the Implements and Machines of the Farm with Dissertations elucidating the mechanical principles of construction, and deducing from them rules and practical information, will, we trust, be now deemed obvious.

27. To the mechanic the utility of such knowledge cannot for a moment be doubted; but in some minds there may be some hesitancy as to their utility to the farmer. A brief consideration will, we think, suffice to show, however, that a combination of the knowledge of the operation or duty required of a machine, with that of the mechanical principles involved in its arrangement, and of the best method to be followed in the construction of its parts, will be well calculated to aid even the farmer.

28. *First*, in leading him to see the pecuniary advantages attendant upon securing the services of mechanics whose education qualifies them to perform those duties in accordance with the laws of mechanical science; *second*, in superintending those workmen in the construction of new, or the repairing of old, implements and machines; *third*, in impressing him with the importance of keeping his machines clean and in good repair; *fourth*, in avoiding all unnecessary shocks and strains arising from defective parts, and the loss of power consequent upon the presence of extraneous matters in the moving parts; and, *lastly*, to enable him, in purchasing, to distinguish the machine or implement false in mechanical principle, or defective in construction, from the true and the efficient, so as to convince him that complex arrangements do not necessarily give more accurate work than those of a simpler kind, or that heavy cumbrous materials do not always insure strength.

29. On the importance of a union of theory and practice, a gifted author remarks: "It is a great but a prevalent mistake to suppose, that the inventions

which have of late so greatly augmented our physical happiness, have resulted either from chance or the speculations of men untaught in science. The very reverse has been the case. There is scarcely a valuable mechanical discovery of modern date, which is not in its nature essentially scientific, and dependent upon principles either not generally known, or not to be acquired without considerable research. . . . . If it be urged that men, eminent for their inventions, have at any rate advanced but little beyond mere principle, it may be answered, that it was because those applications of science to the arts, which constitute their inventions, were to be found even in its principles and on its threshold, not because there were not other and even more valuable applications beyond it. . . . . Science in all its departments is rich in knowledge applicable to the wants of society. It is when practical men add to their experience sound views in theory that it is made to contribute its resources to the public welfare. This is, however, an exceedingly rare union. The arts in consequence are vastly behind philosophy. The practical man imagines unreal difficulties in the attainment of scientific knowledge, and consoles himself by underrating the advantages which science has to offer him. The man of science, wrapt up in the pride of abstract reasoning, will not trouble himself to encounter practical difficulties. His vocation is to discover; to smooth the paths, and to extend the domains, of knowledge; it belongs to the other to follow in his steps, and apply it."

30. To these remarks may be added the equally suggestive ones of Mr William Fairbairn of Manchester, one of the most gifted of our mechanicians: "It is absurd to talk against theory, as if a knowledge of the exact sciences was a dangerous and a useless attainment; nothing can be more erroneous than this impression, as, on close inspection, there is no practice without theory, any more than there is no effect without a cause. In the useful arts, theory can only be considered dangerous when it is not reducible to practice; and the real meaning of the term theory, which creates so much alarm in the minds of practical men, is neither more nor less than a series of definite rules by which practice is governed, and through which we derive, from fixed and definite laws, those sound and healthy results which, of all others, it is the primary object of practice to accomplish. In the mechanical arts, how difficult, precarious, and unsatisfactory are the thoughts of men unacquainted with first principles; and how very often does that deficiency lead them into mal-construction, and those errors which a knowledge of science would teach them to avoid. . . . . A knowledge of the exact sciences must be valuable under every circumstance of life, and this knowledge alone united to sound judgment, is irrevocably the forerunner of a sound and perfect construction. I could multiply examples where ignorance—as a pretender to knowledge—has been productive of the most untoward results, not only in abortive attempts at construction, but in those on which the lives and property of individuals depend. It is not an uncommon occurrence to witness in works of this kind, the most glaring imperfections, a waste of material, and a total want of proportion, arising from the absence of this knowledge; and in order to lessen the number of these discrepancies, our practical men should be educated, and that education should be accompanied with the conviction, that sound practice can never be attained without some definite rule for its guidance."

31. To aid the country mechanic, as well as other mechanicians and the farmer somewhat in applying sound principles to the practice of construction, and to point out to them the direction of their studies, should they aim at higher

* MOSELEY's *Mechanics applied to the Arts.* † *Useful Information for Engineers*, p. 4.

excellence in their calling, we shall now give the Dissertations to which we have already alluded, containing established laws and facts, and which we have arranged in the following order, as one affording a succinct and lucid view of their contents,—

32. DIVISION FIRST.—MATERIALS EMPLOYED IN CONSTRUCTION.

33. *Section First.—Stones*—Granite, trap, sandstones, limestones, and brick.

34. *Section Second.—Timber*—Oak, ash, pines—their toughness or resistance to transverse fracture—their cohesive strength—their compressile strength—their treatment.

35. *Section Third.—Metals*—Iron, cast-iron—its properties, and different qualities of cast-iron; wrought-iron—its properties; copper, brass, lead, and zinc—their properties and use in construction.

36. DIVISION SECOND.—PRINCIPLES OF CONSTRUCTION.

37. *Section First.—Strength of Materials*—Strains to which materials are subjected; how to estimate them; form of strongest section of beams.

38. *Section Second.—Framing and Carpentry*—Rules to ascertain the direction and amount of the pressure exercised upon the parts of framework.

39. DIVISION THIRD.—PRACTICE OF CONSTRUCTION.

40. *Section First.—Foundations.*

41. *Section Second.—Masonry—Brickwork*—Footings, tooling, stone-and-brick setting; arches.

42. *Section Third.—Timber-framing*—Gates; working and joining of timbers; rules to calculate the dimensions of parts of timber-framing.

43. *Section Fourth.—Iron-framing*—Gates; methods of securing and connecting the different parts of iron-framing; rules to calculate dimensions of different parts of iron-framing.

44. *Section Fifth.—Machine Construction*—Shafts, bearings, pulleys, teeth of wheels, eccentrics, connecting-rods; fittings; rules to calculate the various parts of machines.

45 DIVISION FOURTH.—FRICTION AND FORCE.

46. *Section First.—Friction.*

47. *Section Second.—Force*—Useful effects of machines; measure of moving power; application of labour; friction-brake; dynamometer.

DIVISION FIRST.—MATERIALS EMPLOYED IN CONSTRUCTION.

48. SECTION FIRST—*Stones, Brick, Tiles.*—Stones useful for the building purposes of the farm may be divided into three great classes—namely, the *Silicious*, the *Calcareous*, and the *Argillaceous*. The silicious are represented by the granites, traps, and sandstones; the calcareous are comprised in the limestones; the argillaceous, being peculiarly liable to atmospheric influences, are by no means durable enough for building purposes, but, being slaty in their structure, they are employed in the construction of roofs.

49. *Granite.*—This, in its several varieties, is the most durable of all the building-stones. Its constituents are—quartz, which is nearly pure silica, and forms the greater part of the rock; felspar, which imparts to granite its peculiarities of character; and mica, which occurs in shining plates of greater or less size. The best granites are obtained in Scotland; they are known as the red and the grey varieties. They are more durable than the granites of the counties of Devon and Cornwall in England.

50. The granular arrangement of felspar, hornblende, and quartz, known as *sienite* or *syenite*, forms a species of granite, the hornblende appearing instead of the mica, and is one of the most durable of the building-stones known. The two substances, hornblende and mica, resemble each other closely in composition—hornblende having, however, a much greater proportion of the black oxide of iron—syenite is as capable of being worked in large blocks as granite, although, from its hardness, like common granite, it is not easily tooled. The durability of this class of building-stones (the granites), in which felspar is present, depends much on the composition of this ingredient. From the potash contained in it, it is more or less obnoxious to atmospheric influences. Care, therefore, should be taken to ascertain the composition of the stones of this class, where large and important works are to be carried on.

51. *Trap* or *Greenstone* is a very hard and durable stone; it is composed of hornblende and felspar. Although a valuable building-stone, its uses are restricted, from the small size and irregular form of the concretions in which it is frequently found. It is also found in some localities in amorphous masses, when it may be raised in large masses. For cottages and rural structures, when used in conjunction with white stone-facings or dressings to the windows, doors, and corners, and with white mortar, it is well adapted, and presents a pleasing appearance. *Basalt*, of the same composition as greenstone, but with a large proportion of iron, is also a durable material as a building-stone; but it occurs in columnar masses and in still smaller concretions than greenstone, and, being harder, is more difficult of being tooled.

52. *Sandstones*, belonging to the silicious class, are composed of grains derived from the wearing down of the silicious rocks, and bound or cemented together by natural cement of an argillaceous, silicious, or calcareous character. Sandstones present a wide range of character, from a state almost as durable as granite, to that but little better than hardened clay. Where the silicious particles are held together chiefly by an argillaceous cement, they rapidly disintegrate under the influence of the weather.

53. Sandstones are easily worked, and divide readily into convenient blocks. From the ease with which it is worked, indeed, some workmen term it "freestone." The best sandstone is that obtained from Craigleith quarry, near Edinburgh; it is in high repute. The grey-coloured sandstones of Forfarshire are very durable. The Yorkshire sandstones are much esteemed for flagging, being hard, and durable, and easily worked. A greenish sandstone, known as Kentish rag, is very durable.

54. In choosing sandstone, preference should be given to that purely silicious; when argillaceous matter is present, the atmosphere will affect its durability. Although generally esteemed from its variegated appearance, sandstone with coloured stripes should be avoided. These coloured parts, arising from the presence of iron, are speedily affected by water, and decay of the stone is thereby hastened. When mica is present in minute quantity, it determines more specifically the stratified character of sandstone, and the stone is then easily worked in blocks.

55. *Limestones.*—This, the last class of stones suitable for the buildings of the farm we have here to notice, is an important one, and presents a large variety of kinds, characterised by as great diversities of composition as the sandstones. The principal constituent of stones of this class is lime. Limestones are impure carbonates, the impurities present giving that diversity of appearance which characterises many varieties, as marble. Any limestone susceptible of a high polish is termed marble, and of this there are many varieties. The

oolite limestones, a new formation, afford the limestones chiefly used for building purposes. Magnesian limestones afford some superior building material. The mountain limestone forms a beautiful and durable building material.

56. In determining the qualities of building-stone, its *cohesiveness*, or resistance to a crushing power, and its *absorbent* power, or that which represents its capability to resist atmospheric influences, are the two points principally considered. In the report of the Royal Commissioners appointed to investigate the qualities of the stone to be used for the Houses of Parliament, a valuable table is given, which we here append. This affords information on the above two points in connection with the most celebrated of the building-stones of the kingdom. In another column the number of grains, disintegrated from each specimen, is given. The amount of disintegration was ascertained by subjecting all the specimens simultaneously for eight days to Brard's process, which closely resembles the action of the usual atmospheric influences on stone. The absorbent column exhibits the bulk of water absorbed by specimens one cubic inch in size, while the cohesive column exhibits the weight necessary to crush two-inch cubes, or blocks of eight cubic inches. Of the two columns of specific gravities, the first exhibits the ordinary specific gravity, the second shows the specific gravity of the solid particles of which each specimen is composed, on the supposition that the water will take the place of the air which occupied the pores before the atmospheric pressure was removed.

Classes and Names of Stones.	Specific Gravities.		Absorbing Power.	Disintegration.	Cohesive Power.
SANDSTONES.					
Craigleith	2.232	2.646	0.143	0.6	28.083
Darley Dale	2.628	2.993	0.121	0.121	25.300
Heddon	2.229	2.643	0.156	10.1	14.168
Kenton	2.247	2.625	0.143	7.9	17.710
Mansfield	2.338	2.756	0.151	7.1	18.216
Park Spring	2.321	2.615	0.112	5.0	27.071
Morley Moor	2.053	2.687	0.221	0.9	10.879
MAGNESIAN LIMESTONES.					
Bolsover	2.316	2.833	0.182	1.5	29.601
Huddlestone	2.147	2.867	0.239	1.9	15.433
Roche Abbey	2.134	2.840	0.248	0.6	13.915
Park Nook	2.138	2.847	0.249	1.8	15.433
Cadeby	1.951	2.846	0.310	6.4	15.180
Jackdaw Crag	2.070	2.634	0.209	3.1	16.951
Bramham Moor	2.008	2.659	0.244	0.7	22.011
OOLITES.					
Ancaster	2.182	2.687	0.180	7.1	8.349
Bath Box	1.839	2.675	0.312	10.0	5.313
Portland	2.145	2.702	0.206	2.7	7.590
Ketton	2.045	2.706	0.244	3.3	9.108
LIMESTONES.					
Barnack	2.090	2.627	0.204	16.6	6.325
Chilmark	2.481	2.621	0.053	9.8	25.553
Ham Hill	2.260	2.695	0.147	9.5	14.421

57. *Brick.*—If properly made, bricks are little inferior in strength, hardness, and durability, to the building-stones in ordinary use. When broken across, their fracture should present a fine, compact, and uniform texture, of a brownish colour. A whole brick, when struck, should give a clear ringing sound. In Scotland considerable prejudice exists against the use of bricks, more especially for domestic structures.

58. SECTION SECOND—*Timber.*—All the varieties of *Fir timber* imported into the country are employed in the construction of farm-buildings, and those kinds are most used in localities which are obtained from the nearest seaports. For example, along the east coast of this country, Memel logs and Baltic battens are used for all such purposes, while on the west coast no timber is to be seen in the construction of farm-buildings but what is brought from America. (1.) Norway and St Petersburg battens, being cut to proper lengths and breadths, form cheap and very durable timber for all farm purposes. The price is, for red from 3d. to 3½d., for white from 2⅝d. to 3d. the lineal foot. The Norway battens are a shade cheaper. The red or white-wood battens make excellent floors, and plain deal doors for inside use. Such flooring is beautifully dressed by planing machinery at Mr Burstall's mills at Leith. (2.) Memel logs are admirably fitted for joisting, windows, outside doors, and all outside work, it being composed of strong and durable fibre, surrounded with resinous matter. It sells for from 2s. 4d. to 2s. 6d. the cubic foot. The greatest objection to its use for small purposes is its knottiness, on which account the Norway battens make handier small scantlings and cleaner door-work. (3.) The American red-pine is excellent timber, being clean, reedy, and resinous. It is seldom or never of so large dimensions as Memel log. It fetches from 2s. to 2s. 2d. the cubic foot. It is fitted for beams, joists, scantlings, windows, and outside doors. (4.) American yellow-pine is well suited to all inside work, and especially that which requires the highest finish, such as bound-doors, window-fittings, and mantelpieces. There is no wood that receives paint so well. The logs are generally of immense sizes, affording great economy of timber in cutting them up. Its price is, for small sizes 1s. 8d., and for large 2s. 3d., the cubic foot. (5.) Swedish 11-inch plank is good and useful timber, but its scantlings are not very suitable for farm-buildings. Stout joists for granaries are made of it, with a ⅝ draught taken off the side for sarking. It forms excellent planking for wheeling upon, and for gangways. It sells, the white wood for from 5d. to 6d., and the red from 6d. to 7d., the lineal foot.

59. In the interior of the country, at a distance from seaports, *home* timber is much used in farm-buildings. Larch forms good scantlings and joists, and is a durable timber for rough work, and so does well-grown Scots fir of good age, and cut down in the proper season; but in its ordinary state its durability is not equal to larch or generally any good foreign timber for rough purposes.*

60. All the timber referred to is derived from the trees belonging to the natural order of *Coniferæ*, or cone-bearing trees. (1.) The Scots fir, *Pinus sylvestris*, is a well-known tree in the forests of this country, and few new plantations are made without its aid, as a nurse for hardwood trees. In favourable situations it grows to a large size, as is evidenced in the Memel log, which is just the produce of the Scots fir from the forests of Lithuania. Aged Scots fir cut down at Ardovie, in Forfarshire, was of as good quality and useful sizes as the best Memel. (2.) The Swedish plank is of the spruce, *Abies excelsa* or *communis*, a tree which, as it is treated in this country, comes to little value, being rough and full of knots. Inspection of a cargo from Sweden, which arrived at Hull in 1808, convinced Mr Pontey that the white deal, which fetched at that time from £14 to £15, 10s. the load of 50 cubic feet, was of common spruce, the planks having been recently sawn, and a small branch left attached

* In vol. ix. p. 165, of the *Transactions of the Highland and Agricultural Society*, will be found a long account of the larch plantations of Atholl, drawn up from the papers of the late Duke of Atholl; and in vol. xii. p. 122, of the same work, is an account of the native pine forests of the north of Scotland, by Mr John Grigor, Forres.

to one of them.* (3.) Whether the Norway pine is the same species as the pine found in some of the forests of the north of Scotland, we do not know. Some writers speak of the Norway batten as of the Norway spruce, called by them *Pinus Abies.* It may be that the white-wood battens are derived from that tree; but the red-wood kind has very probably the same origin as the red-wood of the north of Scotland, which is from a variety of the *Pinus sylvestris*, or *horizontalis* of Don.† (4.) The red pine of Canada is the *Pinus resinosa.* (5.) And the yellow pine is the *Pinus variabilis* or *Pinus mitis* of Michaux, which towers in lofty height far above its compeers. It grows to the gigantic height of 150 feet, and must require great labour to square it to the sizes found in the British market, large as these sizes unquestionably are. 6. The larch, *Larix Europæa*, is a native of the ravines of the Alps of the Tyrol and Switzerland, where it shoots up, as straight as a rush, to a great height.

61. For agricultural implements two kinds of wood are principally used—oak and ash; oak chiefly in England, ash in Scotland, possibly from ash being cheaper in Scotland than oak. Experiments go to prove the superiority of ash for purposes where sudden shocks and severe strains are given to the implements.

62. *Oak.*—The common English oak, *Quercus robur*, is deemed the best for construction. The grain is straight and fine, and well adapted for purposes where stiffness is required. It splits easily into laths. The Sessile oak is considered, from its elasticity and toughness, best for ship-building purposes, but it is somewhat liable to warp and split. It is not so fine-grained as the Robur oak, and is darker in colour. These English oaks take a long period to come to maturity—nearly 100 years. The American oak is of more rapid growth than the English, but is not so durable. The red Canadian oak is deemed of little constructive value.

63. Oak is adapted to a vast variety of purposes, and when kept in a dry situation it may be termed practically imperishable. Even in situations of alternate wetness and dryness, it is more durable than other wood used for construction. The colour of the best quality is a light brown; when it approaches to red, the quality is not so valuable. The heaviest wood is always the strongest, and that grown on heavy soil more valuable than that on light.

64. *Ash.*—A hard wood, of compact texture and brownish colour, easily worked when young, but tough and hard when seasoned. Its durability is great when kept dry, but alternations of wetness and dryness cause it to decay. Notwithstanding this defect, it is greatly used for purposes where it is subjected to severe strains and shocks, from its superiority in toughness and elasticity.

65. If we examine the transverse section of the trunk of a full-grown tree, we will find it divided into three parts—the heart, which is the centre part; the sap-wood, which surrounds the heart; and the bark, which forms the outer covering. Of these the *heart* is the valuable part for constructive purposes, the *sap-wood* having little strength, and being very liable to decay from the amount of fermenting matter contained in it.

66. The tree should not be felled till it has attained its maturity; if cut

* PONTEY's *Profitable Planter*, p. 41, 4th edition, 1814; and at p. 56 he relates an anecdote of a person who, though long accustomed to attend on sawyers, was deceived by some Scots fir, which he considered excellent foreign plank.

† See *Quarterly Journal of Agriculture*, vol. xi. p. 530.

before, the timber will not be so strong; if cut after decay has set in, it will be less durable and strong than when cut as above mentioned. The commencement of the decline of a tree is indicated by the decay of the top and the topmost branches. There are differences of opinion as to the *period of the year* when timber should be felled—this having reference to the time when the sap is not in circulation. If the tree should be felled while this circulates, the decay of the tree will be hastened from the highly fermentable nature of the sap. The winter months, and the month of July, are considered the best for felling, as the sap is then believed to be dormant. The researches, however, of M. Boucherie, a gentleman who has devoted much time to investigating the properties of timber, point to midsummer and autumn as the time when the sap is least active.

67. *Seasoning of Timber.*—It is impossible to over-estimate the importance of this part of the duties of the machine and implement maker. Unseasoned timber, from shrinking and warping, may cause material injury to important structures and implements. There are a variety of methods now introduced to effect this important purpose. We shall notice three of these: (1.) Natural seasoning; (2.) Water seasoning; (3.) Hot-air desiccation.

68. *Natural Seasoning.*—On felling, the bark and small branches are to be removed, and the timber as soon as possible cut into balks of convenient size of scantling. These are to be removed at once, and piled under drying sheds, where they are subjected to the free circulation of the air, yet protected from the direct action of the sun, wind, and rain. The great object to be attained is uniform drying of the whole timber; all partial and unequal drying only causes warping and shrinking. No timber should be used for constructive purposes until it has been subjected at least two years to this seasoning process. For the usual purposes of the carpenter, timber is considered sufficiently seasoned when it loses about one-fifth of its weight when green.

69. *Water Seasoning.*—This consists in placing the timber in water, with a view to use the latter as a medium to carry off the soluble matter, which is the principal cause of decay. Although much recommended by some, it is considered by good authorities of doubtful utility.

70. *Hot-air Desiccation.*—The best process, and one which has proved itself thoroughly successful, is that introduced by Messrs Davison and Symington. The following is a brief description of it: The timber to be dried is placed in proper positions in a close chamber, into which is forced, by means of fanners, a powerful current of highly heated air. This air is heated by passing through a series of pipes, which are arched over, and form the upper part of the furnace. Some idea may be formed of the complete nature of the process, when we mention that a violin, which had been in use for many years, and was considered thoroughly dry, lost a considerable per-centage of its weight when subjected to the action of the currents of heated air. The same result was obtained in subjecting a piece of wood, which had lain for a great number of years exactly over a smith's forge, which had been in constant use.

71. In regard to the composition of wood, and its chemical properties, "It is considered by chemists that dry timber consists, on an average, of 96 parts of fibrous and 4 of soluble matter in 100, but that their proportions vary somewhat with the seasons, the soils, and the plant. All kinds of wood sink in water when placed in a basin of it under the exhausted receiver of an air-pump, showing their specific gravity to be greater than 1.000," and varying from 1.46 (*pine*) to 1.53 (*oak*). . . . . "Wood becomes snow-white when exposed to the action of chlorine; digested with sulphuric acid it is transformed first into gum, and,

by ebullition with water, afterwards into grape sugar. . . . . Authenreith stated, some years ago, that he found that fine sawdust, mixed with a sufficient quantity of wheat flour, made a cohesive dough with water, which formed an excellent food for pigs; apparently showing that the digestive organs of this animal could operate the same sort of change upon wood as sulphuric acid does. . . . . The composition of wood has been examined by Messrs Gay-Lussac and Thenard, and Dr Prout. According to Dr Prout, the oxygen and hydrogen are in the exact proportions to form pure water; according to the others, the hydrogen is in excess." *

72. "When minutely divided fragments of a trunk or branch of a tree," as M. Raspail observes, "have been treated by cold or boiling water, alcohol, ether, diluted acids and alkalies, there remains a spongy substance, of a snow-white colour when pure, which none of these reagents have acted on, while they have removed the soluble substances that were associated with it. It is this that has been called *woody matter*, a substance which possesses all the physical and chemical properties of cotton, of the fibre of flax, or of hemp."

73. "On observing this vegetable *caput mortuum* with the microscope, it is perceived to be altogether composed of the cells or vessels which formed the basis or skeleton of the living organs of the vegetable. They are either cells which, by pressing against each other, give rise to a network with pentagonal or hexagonal meshes; or cells with square surfaces; or else tubes of greater or less length, more or less flattened or contracted by drying; sometimes free and isolated, at other times agglomerated, and connected to each other by a tissue of elongated, flattened, and equilateral cells; or, lastly, tubes of indefinite length, each containing within it another tube formed of a single filament spirally rolled up against its sides, and capable of being unrolled under the eye of the observer simply by tearing the tube which serves to support it. We find the first in all young organs, in annual and tender stems, in the pith of those vegetables that have a pith, and always in that of the monocotyledons. It is in similar cells that the fecula is contained in the potato. The second is met with in all the trunks and woody branches of trees. The tubes and the spirals (*tracheæ*) are found in all the phanerogamous plants. These are the organs which constitute the fibre of hemp, of flax," &c.

74. "Experiment, in accordance with the testimony of history, proves that, if excluded from the contact of moist air, woody matter, like most of the other organised substances, may be preserved for an indefinite period." The plants found in coal-mines, the wood, linen cloths, bandages, and herbs and seeds found in the coffins of Egyptian mummies, have all their characters undecayed, and yet these tombs are in many cases nearly 3000 years old. "But if the woody matter be not protected against the action of air and moisture, the case is very different. By degrees its hydrogen and oxygen are disengaged, and the carbon predominates more and more. Thus the particles of the texture are disintegrated gradually, their white colour fades, and passes through all the shades till it becomes jet-black; and if this altered woody matter be exposed to heat, it is carbonised without flame, because it does not contain a sufficient quantity of hydrogen. Observe, also, that the cells of woody matter contain different sorts of *substances tending to organise*, and that these are mixed and modified in many different ways." . . . "Woody matter, such as I have defined it, being formed of 1 atom of carbon and 1 atom of water, as soon as it is submitted to the action of a somewhat elevated temperature, *without the contact of air*, experiences

* URE's *Dictionary of the Arts*—art. "Wood."

an internal reaction, which tends to separate the atom of water from the atom of carbon. The water is vaporised, and the carbon remains in the form of a black and granular residue." *

75. Now, if any means could be devised by which the substances in the cells of woody matter could be deprived of their tendency to organise when in contact with common air, wood might be rendered as permanently durable as the grains of wheat which have been found undecayed in Egyptian mummies, and even more so. This discovery seems to have been made by Mr Kyan. In contemplating the probability of the use of home timber being much extended in the construction of steadings, when the young woods at present growing shall have attained their full growth, it may be proper that the growers of wood, and the farmers on the estates on which wood is grown, be made aware of this mode of preventing timber being affected by the dry-rot. What the true cause of dry-rot is, has never yet been determined, but it frequently shows itself by a species of mildew which covers the timber, and the action of which apparently causes the wood to decay, and crumble down into powder. The mildew, however, is neither the dry-rot nor its cause, but its effect. It is distinctly seen by the microscope to be a fungus; and as the fungus itself is so minute as to require the aid of the microscope to be distinctly seen, its seeds or spores may be supposed to be so very minute as to be taken up by the spongioles of trees.

76. The principle upon which the chemical action of the corrosive sublimate—the substance used by Mr Kyan—upon vegetable matter preserves the timber, is easily explained. All plants are composed of cellular tissues, whether in the bark, alburnum, or wood. The tissue consists, as you have seen, of various-shaped cells; and although they may not pass uninterruptedly along the whole length of the plant, as M. de Candolle maintains, yet air, water, or a solution of anything, may be made to pass through the cells in their longitudinal direction. Experiments with the air-pump have proved this beyond dispute. Those cells, and particularly those of the alburnum, contain the sap of the trees which, in its circulation, reaches the leaves, where its watery particles fly off, and the enlarging matter of the tree, called the albumen, remains. Albumen is the nearest approach in vegetables to animal matter, and is therefore, when by any natural means deprived of vitality, very liable to decomposition, particularly that which is connected with the alburnum or sap-wood. Now, corrosive sublimate has long been known to preserve animal matter from decay, being used to preserve anatomical preparations; and even the delicate texture of the brain is preserved by it in a firm state. The analogy between animal and vegetable albumen being established, there seems no reason to doubt the possibility of corrosive sublimate preserving both substances from decay; and, accordingly, the experiments of Mr Kyan with it on albuminous and saccharine solutions have confirmed the correctness of this conjecture. The prior experiments of Fourcroy, and especially those of Berzelius, in 1813, had established the same conclusions, though neither of these eminent chemists had thought of their practical application to the preservation of timber. Berzelius found that the addition of the *bichloride* (corrosive sublimate) to an albuminous solution, produced a *protochloride* of mercury (calomel), which readily combined with albumen, and produced an insoluble precipitate. This precipitate fills up all the cellular interstices of the wood, and becomes as hard as the fibres.

77. Even after timber has been subjected to this process, it is requisite to give the air free access to it by means of ventilation, and for that purpose, where timber is covered up, which it is not likely to be in a steading, small openings,

* Raspail's *Organic Chemistry*, translated by Henderson, pp. 141-164.

covered and protected by cast-iron gratings in frames, should be made through the outside walls.

78. With regard to the expense of this process, which is a material consideration to those who have large quantities of timber to undergo the treatment, it costs for steeping 10s. the load of 50 cubic feet. A tank, fitted up to steep large scantlings and logs, costs about £50, and the process may cost 3d. or less the cubic foot to those who construct a tank for themselves.

79. The patent, we believe, has now expired, so that parties may use the process without fees. The solution is prepared in the proportion of about 1 pound of the corrosive sublimate to 5 gallons of water. The expense per load, as above stated, is divided equally between the solution and the labour in applying it. As regards the efficiency of the system, considerable discrepancy of opinion exists. On the Great Western Railway, after six years' trial, some samples of the wood subjected to the process were found "as sound as on the day on which they were first put down." On the London and North-western Railway the process was found, on the contrary, so unsatisfactory as to be given up.

80. Other plans for preserving timber have been introduced, of which the three most important are known as Burnett's, Bethell's, and Payne's: of these we offer a short description.

81. The process patented in 1842 by Sir William Burnett consists in impregnating the timber with a solution of the chloride of zinc. From recorded experiments, the process seems to be efficient. The preparation of a load of timber by this method is about 16s. The solution is prepared in the proportion of 1 pound of chloride of zinc to 10 gallons of water.

82. In Bethell's process, oil of tar and other bituminous matters containing creosote are used to impregnate the wood. The wood is not only immersed in the solution, but it is forced into the fibres by pressure. The wood to be impregnated is placed in close tanks filled with the solution; the tanks are then closed up, and the air exhausted from their interior; more solution is then pumped in for a period of six or seven hours. The wood is finally taken out thoroughly saturated with the solution, and weighing considerably heavier. The process is said to perfectly coagulate "the albumen in the sap, thus preventing its putrefaction." A load of timber is treated at a cost of from 10s. to 15s. In using the oil of tar it is necessary to deprive it of its ammonia, otherwise the wood becomes brown and soon decays. Timber for farm purposes may be simply Bethellised by painting the surface over with the *hot* oil of tar, or by immersing it in a tank of the hot solution. This will not give such beneficial results as when impregnated under pressure, but will nevertheless tend to preserve the timber for a considerable time from atmospheric influences. The cost of the oil, as sold by the patentee, is stated at 4d. per gallon, this including the right or licence to use the process. On the whole, judging from the almost unanimous evidence in favour of the process, and the ease with which it can be adopted, we incline to think that it is the best adapted for farm constructions.

83. In Payne's process (patented 1841) the wood is impregnated by pressure with a solution of earthy or metallic substances; and these substances, by chemical decomposition, preserved within the material in an insoluble state. Thus, if a solution of sulphate of iron is forced into the wood, a second solution is forced in of any of the carbonate alkalies, which "decomposes the salt, and renders the iron insoluble."*

* See *Transactions of the Highland and Agricultural Society* for 1857, p. 12—art. "The Preservation of Timber."

84. SECTION THIRD—*Metals.*—The metals used in construction are iron, copper, brass, zinc, and lead.

85. *Iron.*—The two varieties of this material are cast-iron and wrought-iron.

86. *Cast-iron* is generally divided into two classes, grey and white, between which there exist very marked differences. When of good quality, grey cast-iron is slightly malleable, and files easily when the skin or outer crust is removed. The fracture presents a granular appearance—grey in colour and metallic in lustre, as if grains of lead were on the surface. Grey is smoother and tougher than white cast-iron.

87. White cast-iron, when broken, presents a fracture of a distinctly marked crystalline character, the colour white, and instead of a metallic it possesses a vitreous lustre, or a light somewhat similar to that reflected from a series of small crystals. This quality of iron is hard and brittle.

88. The colour and lustre of iron is usually taken as a test of its strength. Where the colour is dark grey, with a high metallic lustre, the iron is of a valuable quality. Where the lustre is less decided, the softness and weakness are increased. Where the colour is a light grey, with a high metallic lustre, the metal is hard and tenacious. The hardness and brittleness of cast-iron become more marked as the colour becomes whiter, and the lustre changes from metallic to vitreous. The extreme of the grey variety is where the colour is dark and mottled—this gives the softest and weakest iron of this class; and of the white variety, where the colour is of a dull greyish-white, with a high vitreous lustre —this giving the hardest and most brittle of this class.

89. But while colour and lustre are taken as tests of strength, a good authority does not think them admissible as tests of the chemical constituents of iron; for though dark-coloured iron is usually weak, grey strong, and white brittle, yet black iron, when chilled, becomes white, although it must be supposed to contain the same quantity of carbon. We therefore conclude that the colour of iron indicates the treatment to which it has been subjected, and in some cases only the quantity of carbon.

90. As a general rule, the grey cast-iron is most suitable where strength is requisite, the white where hardness is required. The best test of the quality is to strike the *edge* of a casting with a hammer. If the blow produces fracture, the iron is brittle and comparatively weak; if the blow indents without breaking, the iron is of good quality.

91. The strength of cast-iron depends upon the quantity of carbon which it contains, and its freedom from impurities. In addition to carbon, cast-iron in this country contains silica, lime, magnesia, alumina, and occasionally some of the phosphates and other admixtures. The iron made from the magnetic ores is the best.

92. When cast-iron contains three per cent of carbon, it is considered to be of the strongest quality; if it contains more than this amount, it is soft and weak; if less, it is hard and brittle.

93. The quality of iron produced at the iron-works throughout the country varies considerably, although, taking an average of the whole, some approach to a uniform standard is obtained. As a mixture of the various irons is understood to produce the best cast-iron, it is of some practical importance to know the "mixtures" recommended by experienced engineers. The object in mixing the different varieties is to obtain the proportion of carbon which gives the greatest strength with the requisite degree of fluidity; and this proportion is regulated by the appearance of the fracture of the several varieties proposed to be used for the mixture.

94. Mr Fairbairn of Manchester, one of our highest practical authorities, gives the following as the best mixture, independently of price:—

Lowmoor, No. 3, ...	30 per cent.
Blaina or Yorkshire, No. 2, ...	25 „
Shropshire or Derbyshire, No. 3, ...	25 „
Good old scrap-iron, ...	20 „
	100

For large and small castings Mr M. Stirling gives the following mixtures: For a heavy casting, several inches in thickness and several hundredweight, a mixture of two proportions of No. 3 to one of No. 1 may be used. When the casting is thin and light (say 2 or 3 cwt.), a larger proportion of No. 1 and a smaller proportion of No. 3 may be used. It is difficult to estimate exactly the quantity of the various irons from their numbers, as these are very arbitrary, the No. 1 of one district differing considerably from the No. 1 of another. Attention should therefore be paid to the appearance of fracture of each quality; and where great nicety is required, it would be advisable to test the strength of each by direct experiment. The London mixture, which by the metropolitan founders is considered to be stronger than country mixtures, is equal proportions, or nearly so, of No. 3 old scrap and No. 1 Scotch hot-blast. Another mixture recommended is, equal proportions of hot-blast iron, old iron, and Blaenavon Welsh iron.

95. Mr M. Stirling's patented mixture of wrought-iron and cast-iron gives "considerably increased powers of resistance to every description of strain, when compared with the unmixed irons." This process of toughening cast-iron consists in fusing simultaneously wrought-iron and cast-iron in a cupola or air-furnace. The result of a series of experiments made in connection with this toughened iron, showed that the relative value, as regards strength, of the unprepared iron and the prepared, was 1 : 1.36—the mean breaking-weight of the unprepared being 38.3, and of the prepared 52.3. Other experiments showed a higher value, however, than this. Mr Fairbairn reports very favourably upon this mixture, and says that, when "judiciously managed and duly proportioned," it "increases the strength about one-third above that of the ordinary cast-iron." With regard to the proportions, Mr Stirling says that "the place from whence the iron comes regulates, to a certain extent, the quality, as a general rule. Scotch iron, generally speaking, requires more, Staffordshire less, and Welsh least of all. The proportions which I should recommend for No. 1 Scotch hot-blast, vary from 24 lb. (of wrought-iron) contained in the cwt., to 40 lb., according to the richness of the iron. No. 2 requires a smaller proportion, say from 20 lb. to 30 lb., also according to its quality. No. 3, generally, I do not recommend for mixture, as it is very often uncertain in itself, and its mixtures are not so certain as the toughened mixtures Nos. 1 and 2. No. 3, Scotch hot-blast, makes an excellent mixture with from 15 to 20 per cent of malleable iron for large castings. The Staffordshire No. 1 will not bear so much as the Scotch, and in the same proportion with Nos. 2 and 3; 20 lb. to 30 lb. would be a high proportion for Welsh No. 1. With Staffordshire No. 2, a small proportion in the same falling ratio as in the Scotch; and with Welsh No. 2, 10 lb. to 15 lb. per cwt. would be sufficient."

96. From the commercial results obtained in the manufacture of cast-iron by the use of the hot-blast, the process is now very generally adopted. The question, therefore, is possessed of considerable interest to the mechanic, Is the strength of cast-iron prepared by the hot blast less than that prepared by the cold? On this point considerable diversity of opinion exists. An interesting series of experiments was carried out by Messrs Fairbairn and Hodgkinson, to determine

the relative strength of hot and cold blast. "From these it was found that the hot-blast irons, when taken collectively from a number of works in England, Scotland, and Wales, gave results rather in favour of the hot-blast; whereas the cold-blast iron, when taken separately, and compared with others, indicated a superior quality of iron to those obtained from the hot-blast." Taking the mean of four kinds of iron experimented upon to ascertain the number of pounds required to tear asunder a bar 1 inch square, it was found that, while the cold took 16,801 lb., the hot-blast took 15,342 lb.; and that, taking the strength of cold-blast as represented by 1000, the ratio of the strength of the hot-blast to it was 928. Again, in ascertaining the force in pounds required to crush a prism an inch square on its base, and 1½ inches high, it was found (taking the mean of four) that while the cold-blast took 99,238 lb., the hot-blast iron took 102,777 lb., the ratio of strength being (cold-blast 1000) as 1000 to 1028. And in the experiments made to ascertain the transverse strength of rectangular bars 1 inch square, laid on supports 4½ feet wide, and broken by a weight in the middle, it was found (taking a mean of eight), that while the cold-blast took 456 lb., the hot-blast took 453 lb., the ratio of strength being as 1000 to 996. "On the whole," says Mr Fairbairn with reference to the point now under consideration, "I am of opinion that the hot-blast does not improve the quality of the Welsh and English irons, but, judging from the experiments, and other indications since these experiments were made, that its application to the Scotch furnaces in the reduction of the blackband ores is an improvement. I am the more confirmed in this opinion from the fact, that although the Scotch irons are not injured by the hot-blast, both the English and the Welsh suffer considerably, as may be seen in the case of the Elsicar, Milton, and Buffery irons."—(See Table in par. 124). As to the effect produced by the hot-blast in the manufacture of iron, the same authority remarks, that "it varies considerably with the quality of the ore and the fuel, and I believe much depends upon the quantity of sulphur present in the coal or coke used. The chemical constituents of the fuel and foreign mixtures in the mine, are considerations of importance in the use and application of the hot-blast; but, generally speaking, I should infer that it has a tendency rather to weaken the iron than otherwise." A large number of experiments were made by the well-known engineer, Mr Robert Stephenson, at the High-level Bridge, Newcastle, to test the merits of the various qualities of hot and cold blast iron. The conclusions to which he considers these experiments point are as follows: (1.) That hot-blast is less certain in its results than cold-blast; (2.) Mixtures of cold-blast are more uniform than those of hot-blast; (3.) Mixtures of hot and cold blast give the best results; (4.) Simple samples do not run so solid as mixtures; (5.) Simple samples sometimes run too hard, and sometimes too soft, for practical purposes."

97. The strength of cast-iron objects depends also much upon their size, and in the way in which they are cast. When the object is very large, the iron softens with slow cooling. When the thicknesses of which it is composed are unequal, the unequal cooling of the parts renders some more crystallised and weaker than others. Hence the endeavour of mechanics to have a uniform thickness in the different parts of castings; and hence, also, the rule which should be strictly attended to—namely, never to take the castings out of the sand while red hot, but to allow them to gradually cool, and to become, in fact, annealed in the sand. We are aware that this, in small foundries, cannot under all circumstances be done, from want of space, and also from economical reasons, inasmuch as the portion of the sand in immediate contact with the metal is burnt, and rendered useless; but where sound work to be depended upon is required,

it is essential that the castings should be allowed to remain in the sand till cooled, and a "perfect and compact mass of crystallisation" is obtained. Mr Fairbairn says that fireproof beams should be allowed to remain in the sand never less than 10 hours, heavy castings 30 or 40 hours. Articles, when cast in the direction of their greatest length, are more dense, and are freer from impurity, than when in the direction of their shortest length. Mr Glynn thinks that castings are strongest when the iron is obtained from an air-furnace in dry sand, and that castings in loam are stronger than castings in open sand. The air-furnace is preferred by high authorities before the blast cupola. Mr Fairbairn states that, in one series of experiments, the iron produced in the air-furnace was 2 per cent stronger than that obtained from the cupola.

98. As regards the relative values of Scotch and English iron, the same high authority states, that he "thinks the Scotch weaker, and that it runs more fluid than the English irons. It is, however, equal in strength and superior in quality to some of the Staffordshire irons, but certainly inferior, as respects strength, to the Yorkshire and Welsh cold-blast iron." The Scotch is generally preferred for the purposes of machinery, as it runs well into the mould, and gives clearly-defined edges. When treating on the Strength of Materials, we shall give a table of the qualities of the best-known irons of the United Kingdom, par. 124.

99. *Wrought-iron.*—The fracture of wrought-iron presents a clear grey colour, with a metallic lustre and granular texture. The appearance of the fracture gives a strong indication of force having been required to tear the fibres asunder. A decided fibrous appearance will be given to the granular fracture, if the fractured bar is drawn out into small bars by means of the hammer. When the fracture presents a crystalline or laminated appearance, the iron is defective. Of defective irons, burnt iron is hard and brittle, of a clear grey colour, and of laminated texture. Cold short iron—so called from its breaking under the hammer when cold—is similar in appearance to burnt iron, the colour, however, being whiter. Hot short iron—so called from its breaking under the hammer while hot—is dark in colour, and has no lustre. This latter defect is indicated by cracks on the edges.

100. Wrought-iron of the best quality is divided into two classes, the hard and the soft. The soft is weaker than the hard, gives easily to the hammer, and presents the fibrous texture in bars of considerable section. The hard is strong and ductile, and only presents the fibrous texture when drawn out into small rods. In testing wrought-iron, bars of not less than 1 inch square or round, and flat bars of not less than half-inch thick, should be used. If of less section, the distinctive features of the fracture will not be sufficiently observable.

101. With respect to iron cast and wrought, a question of some importance has arisen as to whether its internal structure is changed by vibration, or by shocks to which the parts may be subjected. On this point a variety of opinions was elicited before the Royal Commission, somewhat contradictory, however, in their nature. Mr Glynn, in his evidence, states that he considers the structure both of wrought and cast iron is altered by a succession of blows—the wrought to a crystalline structure, the cast to larger crystals; and that he has observed this appearance particularly in axles, mill-shafts, tooth-wheels, crowbars, and crane chains. The latter, even when made of strong fibrous iron, require to be annealed every three years. Mr Fox considered that an internal change is produced in wrought-iron by vibration, and points to an instance where the thread of a screw is cut in wrought-iron, and the part broken across at the tapped part, and at another point distant from this; the tapped part will present the most crystallised appearance.

Mr Fairbairn points out a fact of some importance, that repeatedly making a wrought-iron bar hot, and plunging it into cold water, renders it crystalline, and that annealing is required to restore the fibrous texture. Although percussion renders the fibres more liable to break off short, he thinks that unless it is sufficient to cause a considerable rise in temperature, it does not cause change in the internal structure. Mr Stephenson, the eminent engineer, considers any change in the internal structure to be highly improbable; and cites one instance of a connecting-rod which vibrated 25,000,000 of times, and yet remained fibrous. He also points to the fact that the iron of an axle may not be in the first instance fibrous; for although the drawing out of bars from one to some twenty feet long necessarily renders the texture fibrous, it does not follow that it will become so when the bars are drawn out only from 1 to 6 feet. Mr Brunel takes a still more novel and suggestive view of the matter; and while doubting the change of internal structure, he thinks that the various appearances of different fractures result as much from the mode in which the iron has been broken as from any change of structure. Further, that change of temperature will also produce a variation in the fracture; that iron in a cold state presents a more crystallised fracture than the same iron warmed a little; that wrought-iron does not actually become crystalline and fibrous, but breaks either crystalline or fibrous according to the combination of circumstances under which it is broken. The whole subject, although of great importance to the practical mechanic, is surrounded with difficulties, and all evidence given in connection with it has been more or less conjectural. It is right, however, to state that it is a very general opinion amongst mechanics and philosophers, that iron repeatedly hammered—and by inference subject to repeated vibrations and shocks—becomes completely changed in its internal structure. Numerous instances could be brought forward in proof of this, a most notable one being that of the "monster wrought-iron gun" of Mr Nasmyth, which was fabricated by the agency of the steam hammer, and which burst at the first or second trial, presenting, we believe, all the appearances of cast-iron. Parts of machinery are sometimes cold hammered in order that they may take a higher polish; but if this generally received opinion is correct, the practice is a dangerous one, as they may be much weakened. The same may be said of the practice of repeatedly heating, and plunging in cold water, forged parts of machines. (See above, at the top of the page.)

102. As regards the durability of iron, and the influence of the atmosphere and water upon it, Mr Mallet, in his Report to the British Association, gives some valuable remarks. From his close investigation into the nature and properties of iron he deduced a variety of hints, of which the following are the most useful for our purposes.

103. That iron placed in clear fresh river-water corrodes less than under any other immersion, from the absence of highly-corrosive matters, and from the coat of oxide which is formed, and which is not so easily washed off as in sea water; that castings made in dry sand and loam are more durable when immersed in water than those made in green sand; that cast-iron is more durable when the hard crust is allowed to remain, than when it is removed by chipping and filing; that the greater the bulk of bars the less is the corrosion; that to prevent unequal cooling in castings, the ribs should be made of equal thickness.

104. The methods in general use to prevent corrosion and decay of iron-work, consist in the application of paints. These afford, however, little protection; and a better medium, boiled coal-tar laid on while the iron is hot, is highly recommended. It leaves on the surface a bright varnish, capable of

resisting for a considerable time corrosive agencies. Painting the surface with the hot solution of the oil of tar—Bethellising—is said to be an efficient preservative of iron surfaces.

105. *Copper.*—For constructive purposes this metal is principally used in form of thin sheets. It is very durable, and is little affected by atmospheric influences. Brass is an alloy of this metal and zinc, and is composed—when that kind of it known as British brass of a full yellow colour is wished to be made—of 66.18 parts of copper, and 33.82 of zinc. Its specific gravity is 8.299. For purposes where copper is too soft, and a metal less corrosive than iron is required, gun-metal may be used. This is an alloy of copper and tin in the proportion of 84.29 of copper to 15.71 of tin. To render these alloys easily worked in the various processes of the mechanic, a little lead should be added to the brass, and a little zinc to the gun-metal alloy.

106. The *lead* of commerce is derived from the ore *galena*, which is a sulphuret yielding about 87 per cent of lead and 13 of sulphur. Galena is found in greatest quantity in transition rocks, and of these the blackish transition limestone contains the largest. The ore is more frequent in irregular beds and masses than in veins. The galena lead-mines of Derbyshire, Durham, Cumberland, and Yorkshire, are situate in limestone, while those of the Leadhills, in Scotland, are in greywacke. Great Britain produces the largest quantity of lead of any country in the world, the annual produce being about 32,000 tons, of which the English mines supply 20,000. The rest of Europe does not supply 50,000 tons. The export of lead has fallen off considerably, and its price has experienced a corresponding depression for some years past, on account of the greatly increased production of the lead mines of Adra in Granada, in Spain.

107. *Zinc* is an ore which occurs in considerable quantity in England. It is found in two geological localities—in the mountain limestone and in the magnesian limestone. It occurs in veins, and almost always associated with galena or lead-glance. It is of the greatest abundance in the shape of a sulphuret or blende, or *black-jack*, as the miners call it. There is also a silicious oxide of zinc, and a carbonate, both called calamine. In North America, the red oxide of zinc is found in abundance in the iron mines of New Jersey. The zinc of commerce is derived, in this country, from the blende and calamine. It is naturally brittle, but a process has been discovered by which it is rendered malleable, and it retains its ductility ever after. It is this assumed ductility which renders the metal useful for domestic purposes. "It is extensively employed for making water-cisterns, baths, spouts, pipes, plates for the zincographer, for voltaic batteries, filings for fireworks, covering roofs, and a variety of architectural purposes, especially in Berlin; because this metal, after it gets covered with a thin film of oxide or carbonate, suffers no further change from long exposure to the weather. One capital objection to zinc as a roofing material is its combustibility."

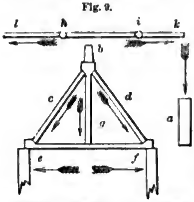
108. The most malleable zinc is derived from Upper Silesia, under the name of *spelter*, which is sent by inland traffic to Hamburg and Belgium, where it is shipped for this country. The zinc of the Veille Montaigne Company enjoys a high reputation; it is considered the purest spelter. Zinc is much lighter than lead, the density being 7.190, while that of lead is 11.352. The tenacity is also greater; thus, while lead has a tenacity of 27.7, zinc has a tenacity of 109.8.

DIVISION SECOND.—PRINCIPLES OF CONSTRUCTION.

109. Section First—*Strength of Materials.*—To enable us to calculate with certainty the size of the materials we use for constructive purposes, it is necessary to be acquainted with the varieties of *strains* to which they are subject, or the manner in which external forces act upon them, and the extent to which different constructive materials are capable of supporting or resisting them.

110. In following out this design, we have taken roofs chiefly as affording the most obvious and palpable demonstration of principles. The demonstration, however, is alike applicable to all species of framing and joinings, whether of machines or otherwise.

Fig. 9.

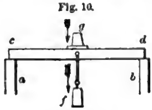


STRAINS TO WHICH MATERIALS ARE EXPOSED.

111. When a piece of timber, stone, or iron, *a*, fig. 9, is pressed in the direction of its length, its strength to resist the action of the force represented by the arrow is called its *compressile* strength, or its *resistance to compression*—meaning the power which the material has to resist being crushed. In fig. 9, the pieces *c* and *d*, pressed upon by the weight *b*, are subjected to a compressile strain or crushing power.

112. The strength which any material has to resist being pulled asunder in the direction of its length, is termed its cohesive power; and any force acting in this way is termed a *tensile* strain—the strength which the material has to resist this being called its *resistance to tension.* The part *g*, fig. 9, suspended from the two pieces *c* and *d*, is in a state of tension; the beam *e f*, acted upon at its extremities by the pieces *c* and *d*, is also in a state of tension, the effect of the pieces *c* and *d* being to pull it asunder in the direction of its length, as shown by the arrows. The weight of the beam *e f*, supported by two walls *e* and *f*, has a tendency to pull asunder the piece *g* in the direction of its length. The iron rod *h i*, acted upon by two pieces, *l* and *k*, in the direction of the arrows, is also in a state of tension.

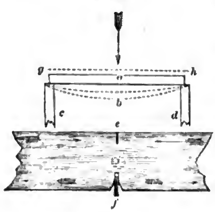
Fig. 10.



CROSS OR TRANSVERSE STRAINS.

113. Where a beam *c d*, fig. 10, is supported at its extremities on two walls *a* and *b*, and pressed upon by a weight acting at its centre as *g*, or by a weight suspended as *f*, it has a tendency to break in two, the weight exerting upon it what is termed a *transverse strain;* and the strength of the material to resist this is called its *resistance to transverse or cross strains.*

Fig. 11.



DEFLECTION OF BEAMS.

114. When a beam or bar *a*, fig. 11, is supported at both ends on walls *c* and *d*, a force, represented by the arrow, acts so as to bend the beam, as shown by the exaggerated lines *b*. The resistance of the material to this is termed its *elasticity*, or *resiliancy;* and the effect produced by the force is called the *deflection* of the beam.

115. All solid bodies subjected to deflection have, within certain limits, a power to resume their original position after the removal of the force which causes the deflection. These limits are termed the limits of elasticity. Little is known as to the extent to which

solid bodies possess this power, or elastic force; the usual assumption is, that a solid body does not take permanently that set or curve which the force gives to it, unless the force exceeds one-third of that necessary to break the body. The experiments of Mr Hodgkinson, however, would seem to point to the fact, that strains, however slight, give a permanent set to all materials on which they act.

116. This strain, causing "deflection," is made up of the two strains tensile and compressile. This may be proved by supposing that we make, in the centre of the beam, a saw-draft or cut on its upper and under side, as at *e* and *f* fig. 11, which represent an enlarged part of the beam *a*. In each of these saw-cuts place a piece of wood or metal just tight enough to be held without dropping out, and then set the beam *a* on the two walls *c* and *d*. As the beam bends, the fibres of the concave or under-side *f* of the beam will be extended, and the saw-cut will open, allowing the piece of metal or wood to drop out: the contrary will have taken place, however, on the upper side *e*; the fibres there will have been compressed, tightening up firmly the piece of wood or metal lying in the saw-cut *e*. The arrows show the direction of the compressile strains acting on *e*, and also the tensile acting on *f*; the fibres, represented by the wavy lines, being contracted on each side of the cut *e*, and elongated or drawn out from the cut *f*. On inspection of the diagram *e f*, fig. 11, it will be seen that there is a portion of the beam in which the fibres have undergone no strain, either compressile or tensile: this part of the beam *i* is called the ***neutral axis***. The experiments of Mr Hodgkinson and Mr Barlow have shown that in iron the neutral axis lies nearer to the concave than to the convex side or surface of the deflected beam; and, in timber, that the neutral axis lies nearest the convex side. In beams of a rectangular section, Mr Barlow calculates the neutral axis in iron to be between one-third and one-fifth of the depth; in timber at three-eighths of the depth.

117. To recapitulate: (1.) A beam is subjected to a ***tensile strain*** when the force tends to draw it or tear it asunder in the direction of its length; (2.) A beam is subjected to a ***compressile strain*** when the force has a tendency to crush or compress its fibres or particles; (3.) A beam is subjected to a ***transverse or cross strain*** when the force has a tendency to break it across the direction of its length; and lastly, (4.) When a beam is subjected to a force tending to ***bend*** it, its capability to resist this is called its ***elastic force***, its ***elasticity***, or ***resiliancy;*** and the effect of the force is called the ***deflection*** of the beam.

118. A vast number of experiments have been made by various authorities, in order to test the capabilities of the different constructive materials to resist the strains which we have described above. These have resulted in affording data from which formulæ have been constructed, aiding the mechanic in estimating the strength of various parts of structures. These are applicable to a wide diversity of practice; but in cases where work of the first order of completeness is desirable, it will be satisfactory to institute direct experiments on the materials intended to be employed. As above stated, the experiments which have been made are applicable to the general qualities of materials; we therefore now give the most important of their results.

119. *Stone.*—In par. 56 we have given a table of the leading qualities of the different classes of stone used for building purposes in this country. We now give a table of the peculiarities of the same classes of stones, showing the weight in tons when the specimens began to fracture; and, in another column, the weight in tons required to crush them. Practically, the first column is the useful one, and may be taken as showing the crushing weight of each specimen.

Description of Stone.	Weight producing Fracture.	Crushing Weight.	Description of Stone.	Weight producing Fracture.	Crushing Weight.
Sandstones.			Oolites.		
Craigleith	1.89	3.5	Ancaster	0.75	1.04
Barley Dale	2.75	3.1	Bath Box	0.56	0.66
Heddon	0.82	1.75	Portland	0.95	1.75
Kenton	1.51	2.21	Ketton	0.69	1.18
Mansfield	0.88	1.64			
Magnesian Limestones.			Limestones.		
Bolsover	2.21	3.75	Barnack	0.50	0.79
Huddlestone	1.03	1.92	Chilmark	1.32	3.19
Roche Abbey	0.75	1.73	Ham Hill	0.69	1.80
Park Nook	0.32	1.92			

120. Stones are chiefly subjected to a compressile, rarely to a tensile strain. Stone is not at all calculated to bear much of a tensile strain; thus, to tear asunder a square inch of sandstone of the qualities as in the above table, only 772 lb. are required; and for oolite, 857 lb. The tenacity of Welsh slate, however, is such that it requires 11,500 lb. to tear asunder a square inch of it. Stones are frequently subjected to transverse or cross strains, as in the case of lintels. From the experiments by Colonel Pasley, it appears that an average breaking-weight in pounds, of prisms 4 inches long, with a cross section of 2 inches on a side, and with a distance of 3 inches between the supports of various stones, was as follows: Craigleith, 1896 lb.; Cornish granite, 2808 lb.; Kentish rag, 4581 lb.; Bath, 666 lb.; Yorkshire, 2887 lb.

121. *Timber.*—In structures composed of timber, the parts subjected to compressile strains are posts or pillars, struts or braces; those subjected to tensile strains, tie-beams and straining pieces; and those to transverse strains, beams thrown across openings, supported at the ends, and sustaining weights.

Description of Wood.	Specific Gravity.	Cohesive strength in lb. per square inch.	Resistance to compression in lb. per square in.
Oak (English)	.934	12.000	6.484
„ (Canadian)	.872	12.000	4.231
Ash	.760	14.130	8.683
Beech	.700	12.225	7.733
Elm	.540	9.720	1.033
Pine (White)	.660	12.340	2.028
Pine (Yellow)	.660	11.830	5.375
Pine (Red)	„	11.800	5.395

122. In calculating the dimensions of beams to resist transverse strains, the experiments of Professor Barlow (*Report to the Commissioners of the Navy*) are particularly useful. The table below shows the breaking weight and elastic

Description of Wood.	Ultimate Stress or Breaking Weight in lb.	Elastic Strength.
Oak (English)	1672	104.
„ (Canadian)	1766	155.7
Ash	2000	113.3
Beech	1550	97.15
Elm	1000	50.
Red Pine	1340	133.1
Riga Fir	1100	96.2

strength in pounds of beams of timber of various kinds, 2 inches in the edge, and 7 feet or 84 inches between the supports.

123. *Cast-Iron.*—Cast-iron for constructive purposes is subjected chiefly to compressile and transverse, rarely to tensile strains. Experiments have therefore been directed principally to ascertain its capabilities to resist compression and cross strains.

124. The table below shows the results of experiments instituted by Mr Hodgkinson and Mr Fairbairn to ascertain the properties and strength of

[ABBREVIATIONS.—C. B., *Cold Blast*; H. B., *Hot Blast.*]

Number of Iron in the Scale of Strength.	Names of Irons.		Specific Gravity.	Modulus of elasticity in lb. per square inch, or stiffness.	Mean breaking weight in lb.	Ultimate deflection of 4-feet 6-inch bars in inches and decimal parts.	Power of the 4-feet 6-inch bars to resist impact.	Colour.	Quality.
1	Pinkey, . .	No. 3, C. B.	7.122	17,211,000	581	1.747	992	Whitish grey.	Hard.
2	Devon, . .	3, H. B.	7.251	22,673,650	537	1.009	589	White.	,,
3	Cleator, . .	3, C. B.	7.296	21,359,400	537	1.001	537	,,	,,
4	Oldberry, .	3, H. B.	7.300	22,733,400	530	1.005	549	,,	,,
5	Carron, . .		7.056	17,873,100	527	1.365	710	Whitish grey.	,,
6	Beaufort, .		7.069	16,802,000	517	1.599	807	Dullish ,,	,,
7	Butterley, .	H. B.	7.038	15,379,500	502	1.815	889	Darkish ,,	Soft.
8	Bute, . .	1, C. B.	7.066	15,163,000	491	1.764	872	Bluish ,,	,,
9	Windmill End,	2, C. B.	7.071	16,400,000	489	1.581	765	Dark ,,	Hard.
10	Old Park, .	2, C. B.	7.049	14,607,000	485	1.621	718	Grey.	Soft.
11	Beaufort, .	2, H. B.	7.108	16,301,000	474	1.512	729	Dull grey.	Hard.
12	Lowmoor, .	2, C. B.	7.055	14,509,500	472	1.852	855	Dark grey.	Soft.
13	Buffery, . .	1, C. B.	7.079	15,381,200	463	1.055	721	Grey.	Rather hard.
14	Brymbo, .	2, C. B.	7.017	14,911,666	459	1.748	815	Light grey.	,, ,,
15	Apedale, .	2, H. B.	7.017	14,852,000	456	1.731	791	,, ,,	Stiff.
16	Oldberry, .	2, C. B.	7.059	14,307,500	455	1.811	822	Dark ,,	Rather soft.
17	Pentwyn, .	2.	7.038	15,193,000	455	1.484	650	Bluish ,,	Hard.
18	Maesteg, .	2.	7.038	13,959,500	454	1.957	886	Dark ,,	Rather soft.
19	Muirkirk, .	1, C. B.	7.113	14,003,550	453	1.714	770	Bright ,,	Fluid.
20	Adelphi, .	2, C. B.	7.080	13,815,500	449	1.759	777	Light ,,	Soft.
21	Blaina, . .	3, C. B.	7.159	14,281,466	448	1.726	747	Bright ,,	Hard.
22	Devon, . .		7.285	22,907,700	448	.790	353	Light ,,	,,
23	Gartsherrie, .	H. B.	7.017	13,894,000	447	1.557	998	Light ,,	Soft.
24	Frood, . .	2, C. B.	7.031	13,112,666	447	1.825	841	,, ,,	Open.
25	Lave End, .	2.	7.028	15,787,666	444	1.414	629	Dark ,,	Soft.
26	Carron, . .	3, C. B.	7.094	16,246,966	443	1.336	593	Grey.	,,
27	Dundyvan, .		7.087	16,534,000	443	1.469	674	Dull grey.	Rather soft.
28	Maesteg (marked red)		7.038	13,971,500	442	1.887	830	Bluish ,,	Fluid.
29	Corbyn's Hall,	2, C. B.	7.007	13,845,866	442	1.687	727	Grey.	Soft.
30	Pontypool, .	2.	7.080	13,136,500	440	1.857	816	Dull blue.	Rather soft.
31	Walbrook, .	3.	6.979	15,394,766	440	1.443	625	Light grey.	Rather hard.
32	Milton, . .	3, H. B.	7.051	18,852,500	438	1.368	585	Grey.	,, ,,
33	Buffery, . .	1.	6.998	13,730,500	436	1.064	821	Dull grey.	Soft.
34	Level, . .		7.080	15,452,500	432	1.516	699	Light ,,	,,
35	Pant, . .	2.	6.975	15,280,900	431	1.251	511	,, ,,	Rather hard.
36	Level, . .	2, H. B.	7.031	15,241,000	429	1.358	570	Dull ,,	Soft.
37	W. S. S., .	2.	7.041	14,953,333	429	1.339	554	Light ,,	,,
38	Eagle Foundry,	2, H. B.	7.038	14,211,000	427	1.512	618	Bluish ,,	,,
39	Elsicar, . .	2, C. B.	6.928	12,586,500	427	2.224	992	Grey.	,,
40	Varteg, . .	H. B.	7.007	15,012,000	426	1.450	621	,,	Hard.
41	Colsham, .	1, H. B.	7.128	15,510,066	424	1.532	716	Whitish grey.	Rather soft.
42	Carroll, . .	2, C. B.	7.069	17,036,000	419	1.231	530	Grey.	Hard.
43	Muirkirk, .	1, H. B.*	6.953	13,294,400	418	1.570	656	Bluish grey.	Soft.
44	Brierley, .	2.	7.185	16,156,133	418	1.222	494	Dark ,,	,,
45	Cœd-Talon, .	2, H. B.	6.969	14,322,500	416	1.882	771	Bright ,,	,,
46	Brak Barrow,	C. B.*	7.172	13,413,000	416	1.736	724	Grey.	,,
47	Cœd-Talon, .	2, C. B.*	6.955	14,304,000	413	1.470	600	,,	Rather soft.
48	Samakoff, .	C. B.	7.216	14,909,000	372	1.160	418	Bluish grey.	Soft.
49	Monkland, .	2, H. B.	6.916	12,259,500	403	1.762	709	,, ,,	,,
50	Leys Works, .	1, H. B.	6.957	11,539,333	392	1.890	742	,, ,,	,,
51	Milton, . .	1, H. B.	6.976	11,974,500	369	1.525	538	Grey.	Soft and fluid.
52	Plankynaston,	2, H. B.	6.916	13,341,633	357	1.366	517	Light grey.	Rather soft.
53	Elba,* . .			21,494,400	235	.487	115	Like zinc.	Hard & brittle.

cast-iron from the principal ironworks in the kingdom. In the table each bar is reduced to exactly one inch square, and the transverse strength, which may be taken as the criterion of the value of each iron, is obtained from a mean between the experiments upon it—first, in bars 4 feet 6 inches between the supports; and next, in those of half the length, or 2 feet 3 inches between the supports. All the other results are deduced from the bars 4 feet 6 inches long, which have not been introduced into the table. In all cases the weights were laid on the middle of the bar.

125. The following table shows the results of experiments, made by Mr Hodgkinson, to ascertain the tensile and crushing force in pounds and tons of well-known varieties of iron; also the proportion existing between these powers. Mr Hodgkinson calculates the crushing force of cast-iron to be 43.5 tons per square inch, and the tensile to be 6.6 tons; which, on the average, makes the resistance of cast-iron to compression 6½ times its resistance to tension. Hence its value in constructive purposes for struts, posts, beams, &c.

Description of Iron.	Tensile strength per square inch of section.		Height of Specimen.	Crushing strength per square inch of section.		Ratio of the power to resist tension and compression.	
	lb.	tons.	Inch.	lb.	tons.		mean.
Lowmoor iron, No. 1,	12,694 =	5.667	¾ 1½	64,534 = 56,445	28.809 25.198	1 : 5.084 1 : 4.446	1 : 4.765
Do. do. No. 2,	15,458	6.901	¾ 1½	99,525 92,332	44.430 41.219	1 : 6.438 1 : 5.973	1 : 6.205
Clyde iron, No. 1,	16,125	7.198	¾ 1½	92,869 88,741	41.459 39.616	1 : 5.759 1 : 5.503	1 : 5.631
Do. do. No. 2,	17,807	7.949	¾ 1½	109,992 102,030	49.103 45.549	1 : 6.177 1 : 5.729	1 : 5.953
Do. do. No. 3,	23,468	10.477	¾ 1½	107,197 104,881	47.855 46.821	1 : 4.568 1 : 4.469	1 : 4.518
Blasnaven iron, No. 1,	13,938	6.222	¾ 1½	90,860 80,561	40.562 35.964	1 : 6.519 1 : 5.780	1 : 6.149
Do. do. No. 2, 1st sample,	16,724	7.466	¾ 1½	117,605 102,408	52.502 45.717	1 : 7.032 1 : 6.123	1 : 6.577
Do. do. No. 2, 2d do.	14,291	6.380	¾ 1½	68,559 68,532	30.606 30.594	1 : 4.797 1 : 4.795	1 : 4.796
Calder iron, No. 1,	13,735	6.131	¾ 1½	72,193 75,983	32.229 33.921	1 : 5.256 1 : 5.532	1 : 5.394
Coltness iron, No. 3,	15,278	6.820	¾ 1½	100,180 101,831	44.723 45.460	1 : 6.557 1 : 6.665	1 : 6.611
Brymbo iron, No. 1,	14,426	6.440	¾ 1½	74,815 75,678	33.399 33.784	1 : 5.186 1 : 5.246	1 : 5.216
Do. do. No. 3,	15,508	6.923	¾ 1½	76,133 76,958	33.988 34.356	1 : 4.909 1 : 4.963	1 : 4.936
Bowling iron, No. 2,	13,511	6.032	¾ 1½	76,132 73,984	33.987 33.028	1 : 5.635 1 : 5.476	1 : 5.555
Ystalyfera anthracite iron, No. 2,	14,511	6.478	¾ 1½	99,926 95,559	44.610 42.660	1 : 6.886 1 : 6.585	1 : 6.735
Yniscedwyn anthracite iron, No. 2,	13,952	6.228	¾ 1½	83,509 78,659	37.281 35.115	1 : 5.985 1 : 5.638	1 : 5.811
Do. do. No. 1,	13,348	5.959	¾ 1½	77,124 75,369	34.430 33.646	1 : 5.778 1 : 5.646	1 : 5.712
Mr M. Stirling's iron, denominated second quality,	25,764	11.502	¾ 1½	125,333 119,457	55.952 53.329	1 : 4.865 1 : 4.637	1 : 4.751
Do. do. third quality,	23,461	10.474	¾ 1½	158,653 129,876	70.827 57.980	1 : 6.762 1 : 5.536	1 : 6.149

126. In connection with cast-iron, it has been a generally received opinion—derived from observation chiefly—that its value increased with the number of meltings it received. To test the truth of this popular notion, Mr Fairbairn instituted a series of experiments, by which he proved that the maximum of transverse strength was only arrived at after the twelfth melting. Thus at the first melting the mean breaking weight being given at 490.0; at the sixth melting it was 438.7, and at the twelfth 692.1. From this it rapidly decreased, till, at the eighteenth melting, it was reduced to 312.7, less than its original strength. Again, with reference to its compressile strength, Mr Fairbairn found that, up to the eighth melting, the strength remained at its usual amount, say 40 per square inch; from the eighth to the thirteenth the compressile strength was increased one-half, say 60; and from the thirteenth up to the eighteenth melting it was doubled.

127. *Wrought-Iron.*—Wrought-iron, in construction, is generally used for parts subjected to a tensile strain, as ties. Mr Hodgkinson's experiments showed the tensile force of wrought-iron to be 24 tons per square inch of

section, or about 4 times that of cast-iron. The resistance to compression per square inch of section is 27,000 lb., or say 12 tons.

128. The mean breaking weight per square inch of section of wrought-iron plates is 50,000 lb., the strength being equal, or nearly so, whether the plates are torn in the direction of the fibres or across them. In a succeeding section we shall enter briefly into the loss of strength incurred by riveting plates together.

129. The experiments of Professor Barlow show that a bar of wrought-iron, 2 inches square in the section, and supported at both ends, 33 inches being the distance between the supports, was deflected .020 (inch) by a weight acting in the middle of the bar equal to 1.75 tons; the deflection being .030 (inch) with a 2-ton weight. The elasticity of wrought-iron bars may be presumed to be injured by a weight of 2½ tons, and destroyed by 3 tons.

130. With reference to the opinion that severe tensile strains are injurious to the bearing powers of wrought-iron, the experiments of Thomas Lloyd, Esq., of Woolwich, go to prove that this is not correct, but that the tensile strain of wrought-iron is not injured by breakages up, even to four times in succession. On this point Mr Fairbairn remarks, that "in practice it may not be prudent to test bars and chains to their utmost limit of resistance; it is, however, satisfactory to know that, in cases of emergency, these limits may be approached without incurring serious risk of injury to the ultimate strength of the material." The experiments of Mr Lloyd also prove that the length of the bar does not affect its tensile strength.

131. We have already (par. 9) pointed out the influence which the mere form of the beam, or the position in which it is laid, has upon its capability to resist strains; and that a beam laid on its edge, as in fig. 3, is capable of supporting a greater weight than when laid flat. Hence, as we pointed out, the reason for making beams thin and deep,—the strength of rectangular beams of this kind, supported at both ends, being as the square of the depth multiplied by the breadth, and divided by the span. Thus a beam having the supports 4 feet wide, and of a size 4 × 2, has a strength of 8; while one of a size 8 × 3 has a strength of 48:—

$$\frac{4 \times 4 = 16 \times 2 = 32}{4} = 8 \qquad \frac{8 \times 8 = 64 \times 3 = 192}{4} = 48$$

Again, suppose a beam 8 by 4, the distance between the supports being 4, to be laid on its *edge*, its strength will be represented by 64; if laid flat, its strength will only be 32. Thus:—

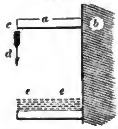
$$\frac{8 \times 8 = 64 \times 4 = 256}{4} = 64 \qquad \frac{4 \times 4 = 16 \times 8 = 128}{4} = 32$$

The proportions here shown (8 × 3 and 8 × 4) are well calculated for beams for flooring purposes, or where they can have cross supports and braces in the manner hereafter shown; but for single beams, the best proportion for the depth to the width is as the square root of 2 to 1: a beam 7 inches deep and 5 wide will meet this proportion nearly.

132. But the form of the beam is not alone that which regulates its bearing strength; the manner in which the load is laid upon it exercises a most important influence. Thus a beam supported at the two ends, *e d*, fig. 10, with the load on its centre, as at *g* or *f*, will bear only half the weight which a beam *a*, fig. 11, will sustain with the weight uniformly distributed over it, as represented by the dotted line *g h*. Thus a beam with the load uniformly distributed

over its surface will bear twice the weight, without breaking, of a beam the load of which is applied at the centre.

Fig. 12.



DISTRIBUTION OF THE LOAD ON BEAMS.

133. Again, if the beam be supported at one end only, as the beam *a*, fig. 12, in the wall *b*, the weight acting in the direction *d* from the point *c*, it will only carry one-fourth of the load which it would do if supported at both ends, as in fig. 10, and loaded in the middle. But in this case also, as in the preceding one, by uniformly distributing the load over the beam, as represented by the dotted lines *e e*, fig. 12, it will carry double the weight.

134. In beams loaded at one end, as in fig. 12, at *c*, the strength (*s*) is in the proportion of the square of the depth (*d*), multiplied by the breadth (*b*), and divided by four times the length (*l*).

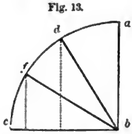
$$\frac{d \times b}{l \times 4} = s$$

135. On the supposition that the length of the beam *a*, fig. 12, is 1 foot, and the weight acting at *c* 1 pound, the strain at the point *b* is called a unit of strain. To calculate the strain to which a beam is subjected at the point *c*, multiply the length (*l*) of the beam by the weight (*w*); the product is the strain at *c*. The strain at any other point is found by the same formula, the length from the point *b* to the extremity *c* (*l*)—$l \times w =$ the strain. These are termed ***units of strain.*** As before stated, if the beam is loaded uniformly, the strain at *b* will be half the strain as when the load is applied at *d*.

136. Theoretically, if a beam, as *c d*, fig. 10, could be fastened immovably at both ends, instead of being merely supported, as in practice; if the load was distributed equally over it, its strength would be increased in the proportion of three to two. If the load was acting in the middle, as at fig. 10, the fracture would be in three places instead of one. Hence may be deduced the truth, that a beam supported at different points, as by passing over partition walls, or supported by struts or ties, is stronger than if it had no such supports.

137. The horizontal position is the weakest in which a beam can be placed; as the beam is made to incline, its strength increases in proportion to the angle till it reaches the perpendicular, where it is greatest. The relative strength of beams placed at different angles may be ascertained thus: Let *a b*, fig. 13, be an upright beam; draw *b c* perpendicular, and equal to *a b*. Incline the beam to the point *d*, drop from *d* a line perpendicular to *b c*, cutting it in the point *e*. The strength of *b d* will diminish as the distance *b e* increases; thus the strut *b f* is as much weaker than *b d*, as *b g* is longer than *b e*. Where the vertical position of *a b* is changed to the horizontal one *b c*, the beam is laid in its weakest position. The strength of a vertical piece *a b* is to that of a strut *b d* as the distance *b a* is to *b e*.

Fig. 13.



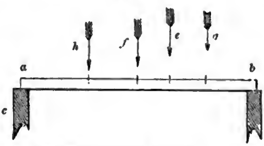
STRENGTH OF BEAMS AS THEIR INCLINATION.

138. The strength of a horizontal beam to resist transverse strains is much influenced by the distance between the supports *c* and *d*, fig. 11. Thus beams decrease in strength as the distances between their supports increase.

139. Where the load is applied to a beam supported at both ends more upon one side than another, the strain on the beam is less than if the weight was applied in the centre, in proportion as the weight is brought nearer the end or point of support. Thus in fig. 14, let the weight upon the beam *a b*, supported

at the ends by the walls $c\,d$, be acting at the point b, and let the point f be the centre of the beam. Multiply the length $c\ e$ by the length $e\ a$, and square the length $f\ a$ or $f\ b$, the products of these will show the proportion the pressure of the weight e decreases, as it is made to bear upon the beam nearer the end. Thus, let the length of the beam $a\ b$ between the supports c and d be 14 feet, and the weight e acting at a point 5 feet from the end b, and of course 9 feet from a, then $5 \times 9 = 45$—$7 \times 7 = 49$ ($f\,b^2$ or $f\,a^2$). The pressure on the beam $a\ e$ by the weight acting at b, compared with that, if the weight acted at f, is thus as 45 to 49.

Fig. 14.



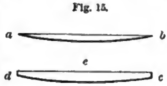
PRESSURE ON BEAMS AT DIFFERENT POINTS.

140. We have shown (pars. 134 and 135) how the strain is calculated to which a beam is subjected by a weight acting at its extremity, when the beam is supported at one end. In the case last given (par. 139, fig. 14) to calculate the strain at the points a and b, fig. 14, where the beam is supported at the two ends, let the weight represented by the arrow e be equal to 200 lb., and the length of $a\ b$, as before, 14 feet. Multiply the distance $e\ a = 9$ by the weight 200, and divide by the length of the beam, 14, the product will be the pressure sustained at the point b—namely, $128\frac{4}{7}$ lb. To find that at the point a, multiply the distance $b\ e = 5$ by the weight 200, and divide by 14, the product is the pressure required—$71\frac{3}{7}$ lb.

141. The same diagram will illustrate the method used to ascertain the units of strain (par. 135) at other points on the side of that (as e) at which the pressure is applied. Let it be desired to know the pressure at the points g and h. For the pressure at the point g, multiply the weight $e = 200$ by the distance $a\ e = 9$, and the product of this by the distance $b\ g$, say 3, and divide the product by the distance 14 between the supports c and d. To find the pressure at h, multiply e (200) by the distance $b\ e$ (5), and the product by the distance $a\ h$, say 4, and divide the amount thus obtained by the distance $a\ b$ (14), and the product will be the pressure at the point h. In all cases the weight of the beam, as part of the load it has to bear, must be taken into account.

142. From these cases and calculations, the truth of our statement (par. 7) will be evident, that beams, to support cross pressures or given weights, do not require to have their scantling or size uniform throughout their length, but may be tapered. Thus, for a beam loaded at the middle, the stress not being equal at every point of its length, but decreasing towards the point of the supports, as shown in the two last paragraphs (140 and 141), theoretically the form may be that of a parabola, terminating in the points a and b, fig. 15. In practice, however, the ends must have bearing-surfaces; for this purpose the ends d and c may be half the depth of the central point e.

Fig. 15.



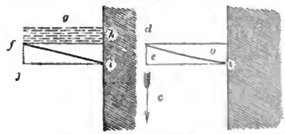
THEORETICAL FORM OF BEAMS.

143. A beam supported at one end, and loaded at the other extremity, as by the arrow c, fig. 16, is as strong when the under side is a parabolic curve from the point a to d, as it would be if rectangular, as shown by the dotted line $a\ e$. Again, the beam $h\,f$, fig. 16, with the load uniformly distributed over its length, as at g, is as strong when the form is a triangle $h\ i\ f$, as it would be if it was a rectangle $h\ i\ j\ f$.

144. So far as we have gone, the section of the beams has been supposed to be rectangular, or square; but by altering the section of a beam it may be

made to carry a much greater weight. This alteration of the form is much more easily carried out in cast-iron than in any other material; hence its value in the construction of beams to support heavy weights.

Fig. 16.



THEORETICAL FORM OF BEAMS.

145. For the investigation to determine the form of cast-iron beams best calculated to support heavy weights, the mechanical world is again indebted to Mr Hodgkinson. These investigations are so complete, and the form deduced from them so universally adopted in improved constructions, that we deem it advisable to enter somewhat fully into a detail of their peculiar features.

146. In commencing the experiments, it was "assumed that a beam, to bear the most, ought to have strong ribs or flanges at top and bottom, with only a thin sheet of metal between the flanges to connect them firmly and stiffly together. In that case the resisting powers of the beam to compression and tension would lie chiefly in the flanges, and be as far asunder as possible, giving to it the greatest attainable power of resistance through leverage." The form of beam experimented upon at the beginning, was that recommended by Tredgold, and considered to be the best; namely, that in which the top and bottom flanges were of equal dimensions, as at fig. 17; which form having been taken as a good one from "a too common generalisation of the fact, that bodies, when not overstrained, offer the same resistance to tension as to compression." Experiment showed Mr Hodgkinson that "the bottom flange ought to be larger than the other; for the bottom flange was torn asunder, showing that to be the weakest part." This was found to be the case when the bottom flange was increased to double or triple its size; and an augmentation of strength was obtained each time considerably greater than the increase of metal used. In the experiments which followed, the flanges were successively increased, particularly the bottom one, till such time as the top flange, and the sheet of metal between the flanges, were no longer able to overpower the continually augmented bottom flange; for up to that time the strength per square inch of section was increased. In the nineteenth experiment the top part first gave way, by the separation of a wedge-like piece of metal; but it was not till the bottom flange at the middle of the beam was six times as great as the top one, and had more matter in it than double the rest of the section. The gain in strength from this form of section over the best of those in common use, seems to be considerably more than one-fourth of the metal. The augmentation of strength obtained by varying the form of the section at the middle of

Fig. 17.

"I" SHAPED CAST-IRON BEAM

Area of Section of Beam in inches.	Area of Section of bottom Flange in inches.	Ratio of Sections of the bottom and top Flanges.	Ratio of Section of bottom Flange to that of whole sec.	Strength per square inch of Section in lb.
2.82	.7	1 to 1	1 to 4	2368
2.87	.98	2 „ 1	1 „ 2.9	2567
3.02	1.2	4 „ 1	1 „ 2.5	2737
3.37	1.57	4.5 „ 1	1 „ 2.14	3183
4.50	2.2	4 „ 1	1 „ 2.05	3214
5.00	2.89	5.5 „ 1	1 „ 1.7	3346
5.41	3.31	„ „	1 „ 1.6	3883
6.4	4.4	6.1 „ 1	1 „ 1.45	4075

the beam, will be best understood from the preceding table referring to some of the experiments.

147. In fig. 18 we give a section of the best form of a cast-iron beam; in fig. 19 a plan; and in fig. 20 an elevation. It will be observed from fig. 19, that in plan the shape of the flanges is not rectangular, but that it tapers from the middle towards the ends *a a* in the form of double parabolas, with the vertex at the middle. By this arrangement the quantity of metal in the bottom flange is reduced without deteriorating the strength of the beam. The ratio of the strength of this beam, and that with the equal flanges, as in fig. 17, is as 4075 to 2368.

Fig. 18.

SECTION OF STRONGEST FORM OF CAST-IRON BEAM.

Fig. 19.

PLAN OF STRONGEST FORM OF CAST-IRON BEAM.

Fig. 20.

ELEVATION OF STRONGEST FORM OF CAST-IRON BEAM.

148. The transverse or lateral strength of square beams of equal length is as the cube of their depth. In cylindrical beams their transverse strength is as the cube of their diameter.

149. In two beams, one square and the other round, the sectional area of which is equal, the strength of the round to the square is in the proportion of 845 to 1000.

150. If the material of a solid cylinder be made to form a hollow tube or pipe, the thickness of which is three-seventieth parts of the diameter, the strength of the hollow cylinder will be to the solid as 2 to 1; that is, the strength of the hollow tube is double that of the solid cylinder.

151. The relative strength of solid and hollow cylinders of equal section, or containing the same quantity of material, is "as the difference between the fourth powers of the exterior and interior diameters of the tubular beam, divided by the exterior diameter, is to the cube of the diameter of the solid cylinder."

152. The capability of a vertical beam, *a*, fig. 9, to resist compression, is not limited to the weight which would crush its fibres, but is considerably under that amount. This arises from the tendency of the beam to deflect or bend laterally, so that, as in the case of a horizontal beam, its strength is regulated by its height: a timber-post should not exceed in height ten times its diameter. Of two solid cylinders of cast-iron, of equal diameter, but of which the height of one is 6 and the other 16 feet, the shortest is capable of supporting 61 cwt., the longest only 22 cwt.

153. Cast-iron columns and pillars are subjected to compression only, but their strength depends upon certain circumstances, as form, &c. We here give Mr Hodgkinson's investigations into this subject, as containing some information calculated to be useful. "1. It was found that a long pillar, with its ends flat, and perfectly immovable, was about three times as strong as another of the same dimensions with the ends rounded, so as to be capable of turning as on a universal joint. When one end of the pillar was rounded and the other flat, according to the definitions given above, the strength was an arithmetic mean between that of the other two. In other words, if three long pillars be formed all of equal diameter and length, and one pillar has both ends made round, another one end round and one flat, and the third both ends flat, the strength of these pillars will be as 1, 2, 3 nearly. Some of the pillars with flat ends

had discs upon the ends to give them an increased breadth of bearing; but this, however necessary in practice, added very little to the strength. 2. A long pillar with both ends flat, or firmly fixed, has nearly the same strength as one of the same diameter and half the length, with both ends rounded as above. 3. If a solid pillar be enlarged in the middle in the proportion of 3 to 2 or upwards of the diameter of the ends, and taper from the middle to the ends like frustrums of two cones whose bases are united in the middle, the strength will be increased more than the weight of the metal by about one-seventh of the whole. This will be the case whether the ends are rounded or flat. 4. *Similar Pillars.*—If long pillars be cast and turned perfectly similar, the diameter being to the length in a constant ratio, the strength was found, from a mean of several experiments, to vary as the 1.865 power of the diameter or any other lineal dimension. It varies, therefore, nearly as the square, but somewhat lower. 5. If a pillar with flat ends be so placed that the pressure it sustains acts diagonally from the extremity of the diameter at one end to the opposite extremity of the diameter at the other, the strength is reduced to one-third, as was proved by several experiments. It is easy to infer that this is a case analogous to that of a pillar with rounded ends. 6. *Relative Strength of Columns of different Materials.*—Representing the strength of columns of cast-iron by 1000, I found the strength in wrought-iron 1745, cast-steel 2518, and Danzig oak 108.8, red-deal 78.5. 7. The properties of columns, enumerated as above, apply to such only as have the length so great that fracture may be considered as having been produced wholly by the flexure of the column. They apply, as appears from my experiments, to all cast-iron columns with rounded ends, in which the length is more than fifteen times the diameter; and to all with flat ends, in which the length is more than thirty times the diameter, or upwards. If the pillars are shorter than this, fracture takes place by flexure, and partly by crushing, and the properties are more complicated than are here described."

154. Although wrought-iron is so much stronger than cast-iron—as shown in No. 6 of the above paragraph to be 75 per cent—it is not, as might be supposed, better fitted for pillars than cast-iron, where compression is only to be guarded against. For the experiments of Mr Hodgkinson have proved the singular fact, that, with a pressure exceeding 12 tons per square inch, it sunk to any degree, or was permanently compressed—it only regaining its original length when the load was under this amount; while, on the contrary, cast-iron, although decreased in length about double the extent of wrought-iron by the same weight, took twice, or perhaps three times, the crushing weight to produce the same effect—that is, to compress it permanently.

155. From these remarks may be deduced the truths in construction, that where the crushing force is more than 12 tons per square inch, wrought-iron for columns is practically useless; and that for this purpose it should only be used where it has also a tensile strain to bear, and this greater than the compressile, as in the case of a hydraulic press, where the pillars sustain not only the weight of the entablature, but also the much greater strain produced by the pump tending to force the entablature upwards. Again, these experiments show the importance of having the ends of pillars perfectly flat which are to sustain compression, and the loss of strength incurred by having them rounded, as in the case of the round and jointed ends of some construction of cranes.

156. SECTION SECOND—*Framing and Carpentry.*—In the various species of construction which the mechanic will be called upon to design, he will rarely

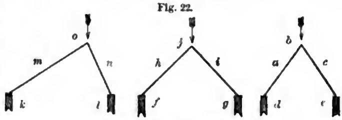
find instances in which a given weight to be sustained can be supported by one resisting part. Where such cases occur, he will have little difficulty in estimating the pressure which these parts sustain: thus, in fig. 21, any weight, represented by the arrow *b*, pressing upon the pillar *a*, exerts obviously a pressure equal to the amount of the weight; and the dimension of the pillar is resolved by a single calculation, having reference to the nature of the material of which it is composed, and of the peculiar strain to which it is subjected.

Fig. 21.

PRESSURE ON A VERTICAL BEAM.

157. But suppose the same weight or pressure, represented by *b*, fig. 22, to be sustained by two supports, *a* and *c*, the united pressure on the pillars *d* and *e* will not be, as might naturally be conjectured, equal to that sustained by the single pillar *a*, in fig. 21, but will be much greater, and that in proportion to the extent of the stretch or distance between the ends of the supports *a* and *c*. Thus, under the same circumstances, the united pressure sustained by the pillars *f* and *g* will be greater than that sustained by *d* and *e*. The pressure *b* or *j*, being dependent upon the angle, or rate of inclination of the supporting pieces *a* and *c* or *h* and *i*, it is obvious that where, in a framing, one piece is at a different angle from another, as *m* is different from *n*, the pressure *o* sustained by the pillars *k* and *l*, on which they bear, will be different in amount.

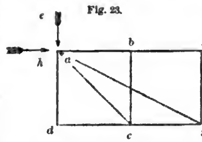
Fig. 22.



PRESSURE UPON INCLINED BEAMS.

158. From these statements it will be seen that, as by a slight alteration in the form or position of the pieces through which a pressure is communicated to other parts, this pressure will be increased, so that a small weight may be made to give a great pressure; and, moreover, as, by changing the relative positions of the pieces, as *m* and *n* in fig. 22, one part *l* will have to sustain a greater pressure than another *k*, it is a matter of importance to the mechanic that he shall be able to estimate the amount and direction of pressures which oblique supports have to sustain. To aid him in this is the object of the following remarks.

Fig. 23.



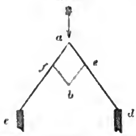
PARALLELOGRAM OF FORCES.

159. Suppose a body, *a*, fig. 23, is pressed by a force represented by the arrow *h*, it will have a tendency to follow the path *a b*; in like manner, the same body, pressed by a force *e*, will move in the direction *a d*. If, however, the body be pressed by the two forces *e* and *h* with equal intensity and at the same time, the path will be in the direction of the line *a c*; this, in fact, being the diagonal of a square, of which the side *a d* is equal to *a b*. But if the force *h* is twice the intensity of *e*, the diagonal will be in the direction *a g*; and a parallelogram would be formed, of which the side *d g* would be equal to *a f*, and twice the length of *a d*. The two forces acting, one in the direction of *a b*, the other in the direction of *a d*, are called the *components*, and the diagonal *a g* the *equivalent*, or *resultant*. The lines *a f*, *f g*, *g d*, *d a*, compose what is usually known as the *parallelogram of forces*. In the diagram given, the force acting in the direction of the diagonal *a g* would be equal to the two forces *h* and *e*; and the method of finding the amount of this force *a g*, to balance the two other forces acting in different directions, *a d* and

a f, is called the *composition of forces;* while the reverse operation—namely, finding two forces which, acting in different directions, as *a d* and *a f*, will exactly balance any single force acting say in the direction *a g*—is termed the *resolution of forces.*

160. Upon a right understanding of the laws relating to the composition and resolution of forces, depends the scientific arrangement of framing, whether required for the purposes of architecture or engineering. Let us exemplify their application to practical purposes.

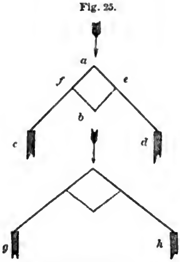
Fig. 24.



METHOD TO ASCERTAIN THE PRESSURE ON INCLINED BEAMS.

161. Let the weight represented by *a*, fig. 24, be equal to—say 8 tons. Drop a perpendicular, *a b*, which would be the direction in which the weight would fall if left unsupported by the two beams *a c* and *a d*. From a scale of equal parts make *a b* equal to the weight 8: thus, if a scale of inches be taken, *a b* should be made 8 inches; if tenths, 8 one-tenths, and so on. From the point *b* draw, parallel to *a d*, a line *b f* cutting *a c* in *f*. Measure *a f* from the same scale of equal parts from which *a b* was taken, and the distance thus formed will be equal to 5 tons. As the inclination of the two pieces is equal, the distance *b e* will be equal to *b f*, and the pressure equal also. Taking the sum of the two pressures, 10 tons, it will be found that the weight *a* exerts a greater pressure upon the two pillars *c* and *d*, than it would if simply pressing upon the pillar *a* in the direction *b*, fig. 21.

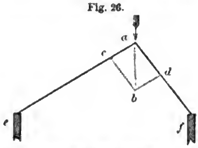
Fig. 25.



PRESSURE AS INCLINATION OF THE BEAMS.

162. To show how the united pressures increase as the angle of inclination decreases, or the distance between the extremities, *c* and *d*, of the pieces *a d* and *a c* increases, let us investigate the cases shown in fig. 25. The weight *a* is the same as in last case, 8 tons. Make *a b*, as before, equal to 8, taken from the same scale of equal parts. Draw *b e* parallel to *a c*; measure *a e*, and it will be found equal to 5½ tons. As the distance *a f* is equal to *a e*, the pressure the weight *a* exerts upon the parts *d* and *c* is 11 tons, which is greater than in the assemblage in fig. 24. In the lower diagram of fig. 25, the weight exerts a pressure still greater than in either of the two last cases, the distance between the points *g* and *h* being greater than between *c* and *d*.

Fig. 26.



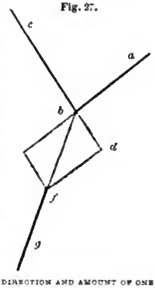
UNEQUAL PRESSURE WITH UNEQUAL INCLINATION OF TWO BEAMS.

163. Take, again, the case as in fig. 26, where the angles which the lines *a e* and *a f* make are unequal, and where, as before stated, the pressures are also unequal. Let the weight be 8 tons as before; draw *a b*, and make it equal to 8. From *b* draw, parallel to *a f*, the line *b c*, and, parallel to *a e*, the line *b d*. Measure *a d* and *a c*—*a d* will give the pressure on the support *f*, 6¾ tons, and *a c* that on the support *e*, 5 tons; the two together giving a united pressure of 11¾ tons.

164. The length of the piece *a e*, fig. 26, has no influence on the relative disposition of the pressure, but the compressile force to which *a e* is subjected depends upon the length; this must be taken into account, and the size increased in proportion to its length. (See par. 166.)

165. These examples we have given come under the head of the "resolution of forces," finding two to balance one, the two acting in different directions. We shall now exemplify the "composition of forces," finding one to balance two.

Fig. 27.

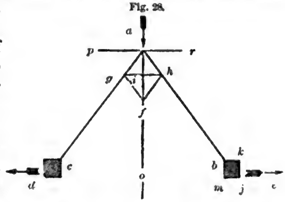


DIRECTION AND AMOUNT OF ONE FORCE TO SUSTAIN TWO.

166. Let *a b*, fig. 27, be a piece of timber pressed with a force of 12 tons in the direction of *a b*; and *c b*, another piece, acted upon with a pressure of 8 tons in the direction *c b*. It is required to find a force which will balance these two, and the direction in which that force shall act. From the point *b* continue the lines *c b* to *d*, and *a b* to *e*. Make, from a scale of equal parts, *b e* equal to 12 (the weight pressing upon *a b*), and *b d* equal to 8 (the weight pressing upon *c b*). From *d*, parallel to *b e*, and from *e*, parallel to *b d*, draw the lines *d f* and *e f*, meeting in the point *f*, and completing the parallelogram *d f e b*. Draw the diagonal *b f*; this will be the direction in which a piece of timber *g* must be placed in order to sustain the two pieces *a b* and *c b*; and the size of which must be proportioned to the strain which the two pieces exert on it. The amount of this strain will be found by measuring the length of the diagonal *b f* in the scale of equal parts, from which *b d* and *b e* were measured.

167. In fig. 28 the weight represented by *a* exerts a pressure upon the pieces *a b* and *a c* in the direction of their length. Supposing them to be resting on a comparatively smooth floor, the tendency of the pressure would be to cause the ends *b* and *c* to slide outwards, and to become further separated. On the supposition, however, that the ends *b* and *c* rested on walls *b* and *c*, preventing the ends from separating as before, the tendency of the weight *a* would be to press the walls *b* and *c* outwards. The amount of the strain thus exerted on the walls, tending to thrust them outwards, is also easily ascertained by the principle of the parallelogram of forces (par. 159).

Fig. 28.

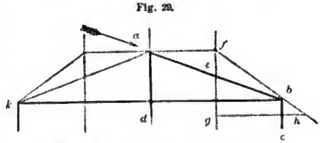


OUTWARD OR LATERAL THRUST ON WALLS EXERTED BY INCLINED BEAMS.

168. For, let *a f*, fig. 28, represent the amount of the pressure of the weight *a*. Complete the parallelogram *a g f h*, and from the points *g* and *h* draw a line at right angles to *a f*. The distance *g i* or *h i* gives the amount of the horizontal pressure at the foot of *a c* or *a b*, tending to thrust out the walls.

169. This horizontal pressure may be ascertained by another method. Continue the central line or axis of one of the beams, as *a b*, fig. 28, to the point *j*, and make *b j* equal to the amount by which *a b* is pressed. Complete the parallelogram *b k j m*: the distance *b k* will be the measure of the horizontal pressure.

Fig. 29.



THE PRESSURE ON BEAMS UNIFORMLY LOADED.

170. Where an inclined beam *a b*, fig. 29, rests its extremities on the walls *b c* and *a d*, and is pressed by a weight as in the direction of the arrow, it exerts a pressure on the wall *b c* in the direction of its length. But where the beam is uniformly loaded throughout its length, as in the case of a roof, the direction of the pressure is estimated differently.

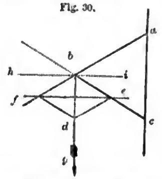
171. Thus, let *e* be the centre of gravity of the beam (in regular prisms and cylinders this is in the axis of the beam and the centre of its length). Through the point *e*, parallel to *a d*, draw the line *e f*; at right angles to this from *a*, draw *a f*, and join *f b*. The direction of the thrust or pressure is in the line *f b*. To ascertain the amount of this pressure, make *f g* equal to the number of tons, pounds, &c., with which the beam *a b* is loaded; from *g*, parallel to *a f*, draw a line cutting *f b* produced, at *h*. Measure the distance from *f* to *h*, and this will give the amount of the pressure on the wall *b c*, while *g h* will give the amount of pressure on the wall *a d*.

172. The same operation is applicable evidently to the case of two inclined beams uniformly loaded, as *a b* and *a k*, *a k* being shown by the dotted lines.

173. We have hitherto shown the application of the composition and resolution of forces to cases of framing, where the pieces are equally inclined to each other after the manner of roofs; we shall now illustrate its application to cases where the pieces have different relative positions given to them.

174. Thus, to estimate the pressure sustained by the pieces *a b* and *b c*, fig. 30, the weight acting from *b* in the direction of *g*, make *b d* equal to the weight represented by *g*. From *d*, parallel to *a b* and *c b*, draw *d e* and *d f*, completing the parallelogram *b f d e*, and draw the diagonal *f e*. The distance *b f*, taken on the scale of equal parts, will show the strain sustained by the piece *a b*, and the distance *b e* the strain on the piece *b c*.

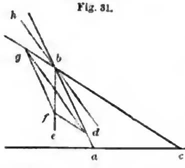
Fig. 30.



DISTINCTION BETWEEN STRUTS AND TIES.

175. To ascertain the pressure sustained by the "guy" *a b c*, and the leg *a b* of the shears for lifting heavy weights, as *b e* in fig. 31, make *b f* equal to the weight represented by *e* from *b*, and draw *f d* parallel to *b c*; the distance *f d* will give the pressure sustained by *b c*, and *b d* that sustained by *b a*.

Fig. 31.



PRESSURE ON THE PARTS OF SHEARS.

176. All pieces in framings subjected to compression are called ***struts***, and those subjected to tension ***ties***. We have already pointed out, in par. 16-19, the necessity of an acquaintance on the part of the mechanic with the offices the various members of a framing are designed to perform, so as to be able to distinguish between those acting as struts and those acting as ties. The following is a method of geometrically ascertaining this difference.

177. Note the direction in which the straining force or weight acts, and in which it would fall if unresisted; the weight represented by *g*, fig. 30, for instance, would fall in the vertical direction *b g*. The sustaining forces are in this case *a b* and *b c*. On the line *b g* of the straining force make *b d* equal to the weight *g*, and complete the parallelogram of *b f d e*. Draw the diagonal *f e*, and from the point *b* draw a line parallel to it, *h i*. The part *b c* being on the side of the line *h i*, which the weight would occupy if allowed to fall, is a ***strut***, and is compressed; while the part *a b*, being on the side of the line *h i* opposite to the direction in which the weight *g* would fall if unsupported, is a ***tie***, and is in a state of tension.

178. Thus in fig. 31, produce *c b* to *g*, and complete the parallelogram *b d f g*; then draw the diagonal *d g*, and through the point *b* draw a line *d h* parallel to *d g*. The part *b a* being on that side of the line *d h* to which the straining force *e* has a tendency to fall, is performing the office of a strut, while $b\ c$ is performing that of a tie, being on the other side of the dividing line $d\ h$. In fig. 28 the line $p\ r$ is the dividing line, and the two pieces, $a\ b$ and $a\ c$, constituting the framing, are both acting as struts.

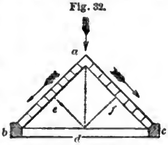
179. Another rule to ascertain a "strut" from a "tie," is to note whether one of the sides of the parallelogram of forces (constructed as already explained in par. 159), as say $d\ f$, fig. 30, parallel to *one* of the pieces $c\ b$, cuts the *other piece* $a\ b$, or whether it cuts a line produced from it. If it cuts the *line produced* from it, as at f, the piece $a\ b$ is a *tie;* if it cuts the piece $c\ b$ itself—as is done by the line $d\ e$ of the parallelogram $b\ f\ d\ e$, at e, the piece $c\ b$ then performs the office of a *strut.* "To this rule," the author of the celebrated article on Carpentry in the *Encyclopædia Britannica*, who gives it, says, "there is no exception." "In general," the same author continues, "if the straining-piece is within the angle formed by the pieces which are strained, the strains which they sustain are of the opposite kind to that which it exerts. If it be pushing, they are drawing; but if it be within the angle formed by their directions produced, the strains which they sustain are of the same kind. All the three are either drawing or pressing. If the straining-piece lie within the angle formed by one piece and the produced direction of the other, its own strain, whether compression or extension, is of the same kind with that of the most remote of the other two, and opposite to that of the nearest."

180. As a ready means in many cases to ascertain whether a piece is performing the office of a strut or tie, it may be considered whether a rope could be substituted for it: if it could, the piece is acting as a tie; if a rope could not be substituted, it is performing the office of a strut. Thus an inspection of the arrangement in figs. 30 and 31 will show that ropes could be easily substituted for the parts $a\ b$, fig. 30, and $c\ b$, fig. 31, but that they could not be used for the parts $c\ b$, fig. 30, and $a\ b$, fig. 31.

181. In roofs, the horizontal pressure tending to thrust out the walls, as in fig. 28, is removed by connecting the feet of the beams $a\ b$ and $a\ c$ by means of a horizontal beam in the direction of $b\ o\ c$. By this arrangement the pressure of the assemblage of beams on the walls is vertical, and is equal to their weight and that of the materials which they support.

182. Three such pieces, $a\ b$, $b\ c$, and $c\ a$, fig. 32, constitute what in framing is termed a *truss.* In par. 11 we pointed out that the strongest known figure was that of a triangle, which could only change its form when the pieces of which it was composed, and the joints by which it was put together, gave way, and that consequently its stability is dependent upon the strength of the materials.

Fig. 32.



THEORETICAL TRUSS

183. This triangular truss, $a\ b\ c$, fig. 32, constitutes the essential feature of *all framing;* and its absence in any framing so called, is at once evidence that the arrangement is defective in principle.

184. It is of all forms the most perfect, as the strains which it imposes on the materials of which it is composed, are such as they are best calculated to bear. Thus, in the case illustrated in fig. 32, the pressure on the beams $a\ b$ and $a\ c$ is similar to that exercised on the column a, fig. 21; that is, it tends to compress them in the direction of their length, as shown by the arrows, and has no tendency to bend or cause them to swerve from their line—so much so, that each beam might be made up of small pieces, as shown, without destroying the integrity of the arrangement. The pressure being thus, tends to force

the lower extremities of the beam asunder; but being connected by the tie-beam *d*, this tendency is only to tear asunder the tie-beam in the direction of its length. And as the pressure on the tie-beam is tensile, its place can be taken by a rope or chain.

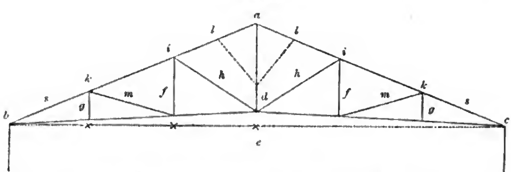
185. Hence, in the construction of a roof to resist a purely vertical pressure acting at the point *a*, fig. 32, all that is essential is the truss *a b c*; care being taken to choose materials strong enough to resist compression or crushing for the parts *a b* and *a c*; and for the part *b c*, a material strong enough to resist tension or drawing asunder. Also, to proportion the pitch or inclination of the roof to the material of which the beams *a b* and *a c* are made; for that which is calculated best to support a compressile strain, will require to be placed at a higher inclination than the material best calculated to support a tensile strain. Thus, where the beams *a b* and *a c* are made of cast-iron, the pitch or inclination will require to be made higher than if wrought-iron was used.

186. In some cases, as in machine framing, the weight to be supported may be vertical, as in fig. 32; but in roofs where the load is uniformly spread over the length of the beams, we have to add certain contrivances, the aim of which is to transfer to, or concentrate at the point *a*, or apex, fig. 32, of the triangle, all the load spread over the beams *a b* and *a c*. For it is to be noted that the triangular truss *a b c* is, in strict principle, only fitted to resist a load at the apex acting vertically.

187. Thus, connect the apex *a* of the truss, fig. 32, with the centre of the tie-beam *d*, by means of another piece, shown by the dotted line *a d*. This will be subjected to a tensile strain; and its lower extremity *d* will afford us starting-points from which we are enabled to carry up other pieces, as *d e* and *d f*, to support the beams *a b* and *a c*, say in the middle of their length, or at any part where the strain is greatest. The pieces *d e* and *d f* are struts, and resist compression; and being on each side of the piece *a d*, they exert an equal pressure on it.

188. But the beams *a b* and *a c* may be of such length that more supports will be

Fig. 33.



SKELETON OF TRUSSED ROOF 30 FEET SPAN, SCALE ⅛ INCH TO THE FOOT.

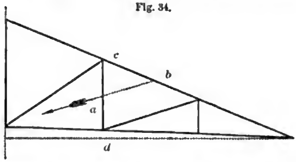
required than *d e* and *d f*. Other struts will then be necessary, and their pressure must also be transferred to the point *a*. How this is done is illustrated in fig. 33. From the extremities *i i* of the struts *h h* drop tensile pieces *i f*, *i f* corresponding to *a d*. The foot of these will give bearing-places for other struts *m m*, the extremities, *k k*, of which are connected with the tie-beam by other tensile pieces *g g*.

189. The pressure of all these struts is transferred thus to the point *a*. The strut *k m* presses against the foot of the tensile piece *f i*, tending to draw it downwards. This pressure, and that of the beam at the point *i*, is transferred to the strut *d h i*, which, pressing on the foot of the tensile piece *a d*, tends to pull down the point *a*.

190. Should further subdivision of the length of the beams *a b* and *a c* be deemed necessary, struts may be carried up to points *l l*, bearing on the tensile piece *a d* near the point *d*. Other struts may also be used, springing from *g g* to the points *s s*.

191. It is only at the central tensile-piece *a d*, fig. 33, that two struts can be used, as at the point *d*, for one being on each side, their pressure is counterbalanced. A strut at any of the other tensile-pieces as *a b*, on the second tensile-piece *c d*, fig. 34, is altogether wrong, for its only tendency would be to push out in the direction of the arrow, or bend the piece *c d*. And it is an axiom in true framing that no tendency to bend a material should be allowed, unless counterbalanced or resisted.

Fig. 34.



TRUSSED ROOF 35 FEET SPAN, SCALE ⅛ INCH TO THE FOOT.

192. In order thus to proportion the strains of the various parts of a framing, it is advisable to design it in straight lines such as we have indicated in the diagrams illustrative of this section; so that all junctions may be made, and made *visible* to the mechanic to meet in a single point. This will also facilitate the adoption of the principle of the composition and resolution of forces, in order to estimate the amount and direction of the pressures to which the various parts are subjected, and from these data to calculate their scantlings or sizes.

DIVISION THIRD.—PRACTICE OF CONSTRUCTION.

193. Section First.—It seems here necessary to premise, that although this work refers specially to the construction of implements and machines, a knowledge of imparting stability to the foundations of the walls and to the beams, joists, and floors of those parts of the buildings which accommodate the machinery, is as necessary to the mechanician and the farmer as the construction of the machines themselves, and to this subject we first devote our remarks.

194. *Foundations.*—It is impossible to over-estimate the importance of a good foundation, for on its being carried out in a proper manner depends obviously the stability of the superstructure. The term "foundation" has a twofold meaning, having reference, first, to the preparation of the ground on which the materials rest; and, secondly, to the arrangement of the materials forming the lower part of the substructure resting on the ground so prepared. Our remarks, therefore, are naturally divided into two classes—1. The choice and preparation of the ground; 2. The arrangement and construction of the "footings," by which name the lower part of walls is designated.

195. *Choice and Preparation of the Ground.*—The best foundations are in compact gravelly soils. This soil is incompressible, dry, little affected by the atmospheric influences, and yields very little laterally. In a soil of this kind the foundation is easily formed; all that is necessary is to dig a trench considerably wider than the width of the walls of the building, and of depth not less than 3 feet. In some instances, a soil of this kind may not be uniformly good, but may present places where the soil is defective, being soft and yielding. When these parts are met with, a simple method to secure a good foundation for structures of no great weight is to dig out the bad earth till

good is met with, filling up the holes so made with sand; or the patches of yielding soil may be rammed well up with layers of small broken stones, as angular in their form as obtainable. The more firmly these patches are rammed, the better.

196. In the preparation of foundations in compact clayey soils, great care must be taken, as they form treacherous foundations in consequence of their being so subject to atmospheric influences. Thus a blue shale may be so difficult to work as in some cases to require blasting with gunpowder, yet so susceptible that in a short time the influence of the atmosphere may reduce it to a thin sludge. In soils, therefore, of this nature, it is essentially requisite to secure the foundation from the action of the air. To attain this the trenches should be dug deep, if possible, to reach the sound compact substratum; the depth should not be less than 30 inches. Before commencing to lay the bottom-courses of the walls, a layer of concrete should be laid along the trenches. The preparation of this material, and the advantages obtained by its use, will be described in par. 202.

197. Firm compact beds of sand form good foundations, but only in circumstances where the sand has no tendency to move laterally—that is, slide from under the foundation. As this lateral tendency cannot in all cases be traced, and as, however firm an examination may show the soil to be, the action of springs, or even of surface water, may give at any time this lateral tendency, it is deemed advisable, in the majority of cases where sand is met with, to adopt special arrangements. These are as follows:—

198. First, simply extend the bearing surfaces on which the walls rest. This is easiest done by making the trenches considerably wider than the width of intended wall, and laying broad and thick flagstones on the surface of the trenches. The width of the stone for a single-storied building should be such as to project a foot beyond the lowest course of the wall—the thickness of the flagstone 3 inches. If the building is to have two stories, add 3 inches to the above breadth and 1 inch to the thickness. It is of essential importance that the stones should have a fair and flat bedding, to prevent unequal settlement. In some cases this extension of bearing surface is given by laying a platform of wood on the sand forming the foundation, this being confined with walls of masonry or brickwork. A much better plan, however, is to dig subsidiary trenches, completely surrounding the main trenches. The main trenches are filled up to the level with concrete, and the subsidiary trenches also. These subsidiary trenches should be deeper than the main trenches. By this arrangement the sand is greatly prevented from sliding laterally from under the foundation-courses. In some cases a firm unyielding soil is found below the bed of sand on which it is proposed to build. In this case piles may be driven down to the solid soil, and the whole of the piles sawn off level. A timber platform may then be put on the piles, on which to rest the superstructure. If possible to be carried out, the better plan will be to dig out the sand, filling up the spaces with concrete or beton.

199. To secure a good foundation in soils of a very soft, yielding character, having a tendency to lateral displacement in almost every direction, it will be necessary to surround the whole area of the foundations with a row of piles driven close together, the heads of the piles sawn off at a level, and to spread over the surface of the soil enclosed by the piles, and over the soil, to some distance beyond the piles, a layer of concrete or beton.

200. In commencing work on the most secure, yet the most difficult class of foundations to work, namely, rock, care should be taken to level all the

trenches perfectly throughout, to fill up all rents either with concrete or masonry, and specially to note that the trenches are deep enough to get rid of all portions which have been subjected to the influence of the weather. Where the ground is unequal, the foundation will require to be "benched out," or cut into a terrace form, as it were. Where the level of these benches varies much, to insure equal settlement of the superstructure, it is recommended to have the whole built up to the same level by courses of masonry.

201. In digging foundations the material should be economically dealt with; that is, the "sod" should be cut carefully off, and removed to some distance; the same with the surface-soil or mould. Sand, if met with, should be retained for mortar, gravel to make concrete with, and clay for puddling purposes. The digging should commence and be carried out, so that, when the excavation is finished, the floor may be as uniform and undisturbed as possible. The whole should then be carefully gone over with a rammer, and the unsound parts excavated, and filled up with concrete or sand. Sand used in this way possesses many advantages, in cases where it is not allowed to slide laterally. Indeed, where this lateral movement can be prevented, sand is recommended in preference to wood for piles, inasmuch as it is capable of yielding and assuming new positions according to the pressure—the lateral pressure which it exerts tending to relieve the vertical on the bottom of the trench.

202. *Concrete* is a compound of lime finely pulverised, gravel or broken stones—the more angular the better—and sand. The whole must be mixed up near the spot where the concrete is to be used, as it sets very quickly. The proportions of this compound vary with the locality, and with the practice of engineers. The lime must be fresh burned, and pulverised without slacking. A proportion adopted in London is five parts of gravel and sand to one of lime. The materials are thoroughly mixed up while dry, and a little water is then added to bring the whole to the consistence of mortar; it is then quickly worked up with a shovel, and applied. In filling in foundations, it is considered by some a good plan to "toss" in the concrete from some height, as it tends to consolidate the mass. A contrary result may, however, be apprehended, as it tends, we think, to separate the constituent parts. When first made, the bulk of concrete is less than the bulk of the materials of which it was composed; but the mass ultimately expands, in the proportion of nearly half an inch in height for every foot of depth.

203. In some instances concrete is applied in blocks as a building material, but both in durability and transverse strength it is very deficient. Away from atmospheric influences, such blocks may be used in the interior of thick walls. As a material for securing a good foundation, and for the prevention of damp, it is exceedingly valuable, and is deservedly in high repute.

204. The term *beton* is applied to any mixture of hydraulic lime with fragments of brick, stone, or gravel. The most economical mixture, and one which is very good, is broken stone or brick, in fragments of the size of pigeon-eggs, with coarse and fine gravel. In preparing beton, the lime is first prepared, with which is next incorporated the finer quality of gravel used. This is then spread out where required to a depth of some 4 or 6 inches, over which the coarse gravel and broken fragments of stone or brick are then strewed, and the whole brought to a well-mixed condition with water by the spade or the lime-hoe. Beton is superior to concrete, especially for foundations under water, or in wet soils.

205. We shall give a few of the proportions usually adopted in making mortar and hydraulic cements—that is, cements calculated to harden under water. *Mortar* is a combination of lime and sand. Lime, in its ordinary state

of carbonate, is useless for building purposes; but when burnt, a new substance is produced, which has a powerful affinity for water: this new substance is termed an oxide of calcium. When water is added to this, a hydrate is formed, which, when combined with sand, forms a new substance again—namely, a silicate. The office which the sand performs is simply to act as neuclei, round which the crystals of carbonate of lime, and the portions of silicate which are formed, may arrange themselves. Sand, therefore, must not be rotten or friable; moreover, it must contain no salt calculated to make the lime soluble; hence the use of sea-sand must be avoided.

206. The *sands* used for the preparation of mortar are generally classed as pit, river, and sea sands. Of these, river-sand is generally considered the best, pit-sand being dirty and sometimes friable; while the sea-sand is objectionable for the reason stated in last paragraph, as also from walls built with it being peculiarly liable to atmospheric influences, soon showing damp, arising from the affinity salt has for moisture. A mixture of coarse and fine sand is better than sand of equal fineness. For good mortar, the proportion of lime to sand should be two and a half of sand to one of lime.

207. *Pure lime*, when reduced to a paste by the addition of water, has no tendency to harden—the lime, after the water has evaporated, returning to its original dry condition. Different effects are produced, however, on different limes by the addition of water: thus in some, termed "rich or fat limes," the bulk is much increased; in others the bulk is very slightly altered. These last are termed "poor" or "meagre" limes, and are those only which, in combination with silica, alumina, and magnesia, have the power of hardening under water. This combination of poor limes with silica, &c. is called a hydraulic mortar or cement.

208. There are various methods of forming this species of *cement*. Smeaton's mortar, as used at the Eddystone Lighthouse, was "composed of equal parts of Aberthaw lime, in the state of hydrate of lime in fine powder, and puzzolano also in fine powder, well beaten till it had acquired the utmost degree of toughness." Puzzolano is a volcanic concrete thrown up from Vesuvius; it is so named from the town Puzzuoli, where it was first found. An artificial puzzolano is prepared by burning clay. The cement or hydraulic mortar used by the Romans was composed of two parts of puzzolano to one of lime. The facing of the London docks was cemented with an excellent mortar, composed of four parts of lias lime, six of river-sand, one of calcined limestone, and one of puzzolano. A good hydraulic mortar may be composed of two and a half parts of burnt clay to one part of blue lias lime, to be pulverised between rollers, mixed and used immediately.

209. What is known as *Roman cement* is made of the masses found within the upper and lower beds of the Lias formation, of which the blue limestone forms the main feature. These masses are known as "septaria," and are burnt with coal. Parker's cement consists of forty-five per cent of clay to fifty-five of carbonate of lime.

210. We may here observe, that any lime that is used on a farm for the purpose of steeps for grain or for mortar, gets leave to lie about in the most careless manner, either under a shed, or at some place contiguous to water, where it had been made up into a mortar. In either case there is waste of a useful article; and in many parts of the country, where carriage is far distant, it is a high-priced article. The lime that is to be used in a dry state should be kept under cover; and all that is required in a season could be held in a cask or small hogshead, to stand in a corner of the cart-shed, but not in the straw-

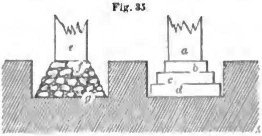
barn, where a little damp may cause it to ignite the straw. With regard to mortar, no more should be made at a time than is used, or it should be carefully heaped together in a convenient place, and covered with turf.

211. *Puddling* is a very simple process, and may be performed in this manner: Let a quantity of tenacious clay be beaten smooth with a wooden hammer, mix with it about one-fourth of its bulk of lime (slacked), which has the effect of deterring worms from making holes in it. After the mass has lain for some time souring, let large balls of it be formed, and thrown forcibly in the bottom of the space required to be puddled, and well rammed down with a wooden rammer, or with men's feet. This should be repeated till the space is filled up.

212. *Stone Footings.*—In the construction of footings, the great object is to give a wide base, to which the vertical pressure of the walls is to be transferred, greater stability being thus given to the structure by diffusing its weight over a larger surface. The width of the base will obviously depend upon the nature of the soil in which the foundation is made—rock of a firm stable character requiring the minimum, soil of a loose and yielding nature, the maximum breadth.

213. The proper thickness of the wall begins usually at the ground-level, the space below, in the foundation-trench, being devoted to the footings, which spread out the farther they proceed from the ground-level line. Two methods are in use for forming the footings of stone constructions, as exemplified in fig. 35. In one method, the lower courses are so made as to form what is called a "set-off," this being formed by one course, as *c*, being narrower than *d*, and *b* narrower than *c*, the wall *a* narrower than *b*. The other method consists in giving a uniform slope or batter, from *g* to *f*, to the footings, upon which the wall *e* is raised. This presents a smaller volume of material than the method at *b c d*, with an equal stability. The breadth of each set-off, where used, should not exceed 4 inches.

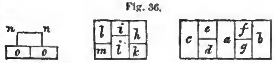
Fig. 35



STONE FOOTINGS—SCALE, ⅛ INCH TO THE FOOT.

214. The largest sized stones are used for the bottom course; and the thickness of stones used for any course should be uniform. The more perfectly levelled the surfaces are the better. If obtainable, stones of size sufficient to go across the foundation should be used. When, for thick walls, all the stones cannot be obtained of breadth sufficient to reach across, the place of every second stone should be taken up with two shorter blocks of the same width and thickness. Thus, in fig. 36, let *a*, *b*, and *c* represent the longest, and *d e f g* the shortest blocks. Another method is also illustrated in fig. 36, where the longest stones, as *h j l*, are two-thirds of the thickness of the wall; and the shortest stones, as *i k m*, one-third. The method of disposition is shown in the diagram. The joints of all the stones should be so disposed that the joints of one course will fall upon the solid parts of the course below, as the joints of *n n* rest on the solid parts of the stones *o* and *o*. This is called "breaking joint."

Fig. 36.



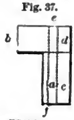
PLAN OF STONE-FOOTINGS—SCALE, ⅛ INCH TO THE FOOT.

215. Where the soil is somewhat compressible, and the stones cannot be obtained with straight surfaces, a plan of forming the foundation is thus recommended: Make the first course with the smaller blocks, well bedding them into the soil or on the concrete; form the next course with the large blocks, binding the smaller stones together, and spreading the weight uniformly over them.

216. The largest stones should be used for the angles of the foundations, par-

ticular care being taken in bedding them; and wherever the soil is liable to moisture, hydraulic cement should be used for the joints. As in walls the pressure is nearly always vertical, the surfaces of the stones to which this is transferred should be horizontal, carefully levelled, and presenting no angular points. The stones of the upper course, as *b*, fig. 35, should be so arranged that the first course of the wall *a* shall rest on the outer stones.

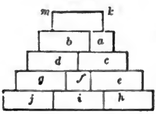
Fig. 37.



HEADER AND STRETCHER (BRICKS)

217. *Brick Footings.*—In brickwork, when a brick is placed with its side parallel to the length of the wall, as *a*, fig. 37, it is called a "stretcher;" when its end is parallel, or its side at right angles to the length of the wall, as *b*, it is termed a "header." In forming brickwork footings, it is advisable to have all the outside courses headers, as *b*. The benefit derived from attending to this is obvious enough on examining the diagram in fig. 37. For, let the line *c d* represent the outside line of the succeeding course, then it is obvious that the brick *a* (stretcher) sustains the pressure of the superstructure over half of its surface only; while the brick *b* (header) sustains it over nearly three-fourths of its surface. We have already shown that the more uniformly (*Strength of Materials*, par. 133) a weight or pressure is distributed over a material, the greater the weight which it can support. Thus by increasing the width of the offset of the footing, as say to the line *e f*, the bearing-surface of each brick *b* and *a* is much reduced.

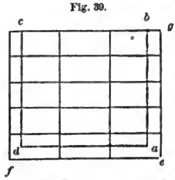
Fig. 38.



FOOTINGS FOR A 14-INCH BRICK WALL—SCALE, ¼ INCH TO THE FOOT.

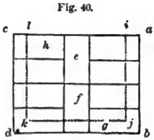
218. In fig. 38 we give a sketch showing the arrangement of brick-footings adapted for a 14-inch wall *a b*, with the footings *c d*, *e f g*, *h i j*. In fig. 39 we give the plan of the footing *h i j*, *f e* being the breadth or thickness of the wall, the length being in the direction *e g*. Make the set-off equal to half the width of a brick, or 2¼ inches, this will give the lines *a d*, *a b*, and *d c*; these two last being, of course, continued as long as the wall. Fig. 40 shows the arrangement of the course *e f g* in fig. 38, the width of which *b d* corresponds to the width *a d* in fig. 39. This course is made up of two rows of headers *g* and *h*, placed on each side of stretchers *e* and *f*. Setting off as before the distance of half a brick breadth, the lines *j k*, *j i*, and *k l* will be obtained, *j i* and *k l* stretching along the wall. Fig. 41 is the plan of the course *c d* in fig. 38, the line *j k* corresponding to *j k* in fig. 40. In this course there are two rows of headers, placed end to end. Set off as before, 2¼ inches, and the lines *b d*, *b a*, *d c*, will be obtained,

Fig. 39.



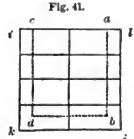
PLAN OF LOWER FOOTINGS OF 14-INCH—SCALE, ¼ INCH TO THE FOOT.

Fig. 40.



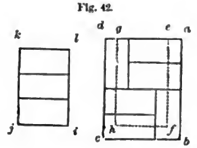
PLAN OF SECOND COURSE OF FOOTINGS—SCALE, ¼ INCH TO THE FOOT.

Fig. 41.



PLAN OF THIRD FOOTING—SCALE, ¼ INCH TO THE FOOT.

Fig. 42.

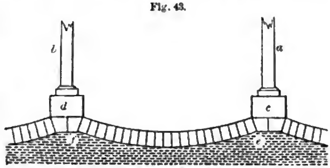


PLAN OF FIRST COURSE OF 14-INCH WALL—SCALE, ¼ INCH TO THE FOOT.

giving the space for the wall as *a b* in fig. 38. Of this course *a b c d*, fig. 42, is the plan composed of headers and two stretchers. If the reader would take tracings of all these sketches, figs. 39 to 42 inclusive, and superpose fig. 40 on fig. 39, and fig. 41 on fig. 40, and fig. 42 on fig. 41, he would find that the joints of all the bricks of each course would lie against the solid parts of the bricks in the course immediately beneath, just as shown in the section in fig. 38. Should a 9-inch wall be required, as shown by the dotted lines *k m* in fig. 38, the bricks will be laid as in plan *i j k l*, fig. 42: *j i* will correspond with *h f*, *i l* with *f e*, and *j k* with *h g*.

219. Where solid foundations are required for pillars, as in the case of a large roof covering a stackyard, &c., and where the ground is of a soft yielding character, the plan of turning inverted arches might be adopted with advantage, as shown in fig. 43, where *c* and *d* are the bottom blocks for supporting the pillars or columns *a* and *b*, and *e f* is one of the inverted arches.

Fig. 43.

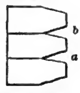


INVERTED ARCHES FOR FOUNDATIONS—SCALE, ⅛ INCH TO THE FOOT.

220. *Stone Masonry.*—The two principal kinds of stone masonry are "ashlar" and "rubble." Ashlar consists of stones cut and dressed to specific sizes; it is the strongest method of building, although, from the expense of dressing the stones, it is not so often followed. The front or outside of an ashlar wall is termed the face, as the inside is termed the back: the stones composing these are, therefore, styled the facing and the backing. Where the courses—that is, the horizontal layers of the stones—are of regular and equal thicknesses, the style of building is called regular coursing; if of unequal thicknesses, irregular or random. The upper surface of each stone, as it lies on the course, is called the "bed;" and the method by which the connection is made between the different stones is called the "bond."

221. For *ashlar-work* the stones are generally from 28 to 30 inches long, 12 to 18 wide, and 5 to 9 inches thick. The sizes will depend upon a variety of circumstances; but, as a general rule, the breadth should never be less than the thickness, and never exceed twice this dimension — the length of the stone not exceeding three times its thickness. Every care should be taken to have the stones well dressed; the closer they fit together, the better the work: unequal settling will certainly result from unequal surfaces, if not actual fracture of the stone from the unequal pressure on the different points. All the surfaces should be at right angles to the direction of the pressure. The practice so often adopted by *scamping* workmen of dressing the stones a few inches from the face, should be carefully avoided. When this plan is followed, voids or empty spaces will be left, as *a b* in fig. 44, and unequal settling, and possibly fracture of the stones at the joints wilt be the result. Where the backing of an ashlar front is of rubble, this tapering-off of the blocks to the back is recommended as affording a good bond between the facing and the small stones composing the rubble backing; but even in this case the stones should be dressed as far back from the face at least as a foot.

Fig. 44.

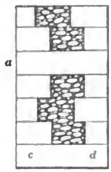


DEFECTIVE ASHLAR WORK.

222. *Bond* in stone-work is obtained generally by the system of header and stretcher, by which the vertical joints of one course fall over the solid parts of the stones above and below—"breaking joint" (par. 214). If the header

reaches from the face to the back of the wall, as *a b* in fig. 45, it is termed a *through;* if only part of the distance, a *binder.* In walls with dressed facing and backing, as in fig. 45, and rubble "filling-in," these "throughs" are essential parts in sound constructions. In laying the blocks in ashlar-work, each block should be lifted into its bed, and the accuracy of the joint tested; if it does not lie fair and perfectly stable, the deflective parts must be observed, the block removed, and the changes desired made. The bed should now be carefully cleansed from dust, stone-chippings, and moistened with water; the mortar should next be laid on the bed, and the block, with its under-side cleansed and moistened, lowered, and settled in its place by blows of the mallet. The joint which goes up against the joint of another block, in the same course, must be as carefully made. The vertical joints must be at right angles to the horizontal ones, and also at right angles to the facing; by this arrangement of the horizontal and vertical joints, the greatest strength possible is given to each block.

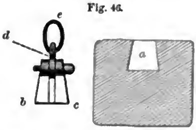
Fig. 45.



MODE OF BUILDING ASHLAR WALLS WITH "RUBBLE" FILLING-IN—SCALE, $\frac{1}{4}$ INCH TO THE FOOT.

223. Heavy blocks are raised and lowered by what is called a "*lewis,*" as illustrated in fig. 46. An aperture, as *a*, is made in the upper surface of the stone; two wedges, as *b c*, of wrought-iron, are made with a slope to correspond to the slope of the aperture *a*; a flat piece *d* goes between them, and the whole are united by the bolt *f*. In using a lewis the bolt *f* is taken out, and one of the tapered wedges, as *b*, inserted in the hole *a*; the other, as *c*, is next inserted; lastly, the piece *d*; the bolt *f* is then passed through them. The chain is attached to the ring *e* passing through *d*, and the tendency of the weight of the stone is only to tighten the wedges *b c* in the hole *a*.

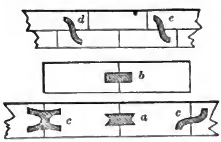
Fig. 46.



LEWIS FOR RAISING BLOCKS OF STONE—SCALE, 1 INCH TO THE FOOT.

224. In ashlar-work, the stones in particular constructions, as embankment walls, &c., are often required to be joined together, as well as one course to those above and below it. To effect this junction, "*dowels*" or "*joggles*" are sometimes used, as at *a* in fig. 47, or as at *b*. These dowels or joggles are made of copper or of slate, or hard stone. Iron "*cramps*" of various shapes are also used; the object being to give them as complete a hold of the stones as possible. These are let into similarly-shaped indentations made in the stone, and run with lead; two of which cramps are shown at *c* and *c*. The connection of the course with another above or below it is also made by means of cramps, as at *d* and *e*. Projections are sometimes made in the bed of one block, and corresponding indentations on the under-side of the other.

Fig. 47.



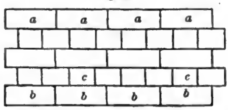
DOWELS, JOGGLES, AND CRAMPS, FOR JOINING BLOCKS OF STONE.

225. *Rubble-work* is of two kinds, coursed and uncoursed, or regular and irregular. In the coursed work the stones are hammer-dressed to sizes nearly uniform; the courses may be of unequal thicknesses. In uncoursed rubble, the stones are prepared by knocking off all the sharp angles. The bedding should be carefully prepared, and the interstices filled in with smaller pieces or chippings pressed into the mortar. As each course is finished, *grout*, or thin mortar, should be applied to the surface, in order completely to fill up all the interstices. Due care should be taken to place the stones in

their natural or quarry-bed position, which is indicated by the laminæ of the stone.

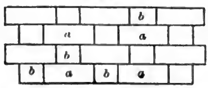
226. Rubble-work is sometimes used as a backing for ashlar-facing. This is by no means a good plan, for, the mode of building being so dissimilar, unequal settlement is likely to take place, and the backing to be separated from the facing. The method illustrated in fig. 45 is a good one, and will be cheaper than solid ashlar-work, and, if carefully built, nearly as strong. The great art in building rubble-work uncoursed, is to place the stones of different sizes in such a way as to interweave with each other, the interstices being well filled up with mortar. To test if rubble-masonry is well built, step upon a levelled portion of any course, and, on setting the feet a little asunder, try, by a searching motion of the legs and feet, whether any of the stones ride upon others. When the stones ride, they have not been properly bedded in mortar. To ascertain if there are any hollows, pour out a bucketful of water on the wall, and those places which have not been sufficiently packed or hearted with small stones will immediately absorb the water.

Fig. 48.



OLD ENGLISH BRICK BOND—SCALE, ½ INCH TO THE FOOT.

Fig. 49.



FLEMISH BOND—SCALE, ½ INCH TO THE FOOT

227. *Brick Walls.*—Since the repeal of the duty on bricks, they are made of all sizes and shapes; but the dimensions of ordinary building-bricks remain still as before—namely, 9 inches long, 4½ inches wide, and 3 inches thick. Each course is thus of the same depth, being regulated by the thickness of the bricks. The facing of brick walls is "set" up in two ways —"old English" and "Flemish" "bond." The former is illustrated in fig. 48; in this the courses are made up of alternate rows of headers and stretchers: *a a*, *b b* are stretchers, *c c* are headers. The "Flemish" bond is illustrated in fig. 49; in this each course is made up of headers and stretchers alternately: *a a* are stretchers, *b b* are headers.

228. The Flemish bond is considered to look the best, but the old English is undoubtedly the strongest. In the Flemish there is comparatively little lateral tie, as the length of the stretchers predominates over that of the headers. In the old English, on the contrary, the bond or connection between the various parts is very complete, the headers giving good bond across the wall, the stretchers along it. As brick walls are apt to split or rupture transversely, or in the direction of their thickness, and laterally in the direction of their length, every attention should be paid to avoid this tendency. Old English bond is preferable to Flemish, on this account chiefly, that the frequency of the headers gives strong lateral bond. To afford the mortar a secure hold of, or to enable it to "key" to the brick, bricks are now sometimes moulded with shallow rectangular indentations on the upper and under sides; into these the mortar is pressed, forming a "key" or hold.

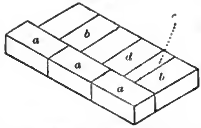
229. Still farther to secure the advantages of a good "bond" in the structure, "bond-timber" is often used to connect the wall longitudinally. This consists of timber of some 3 or 4 inches square, or of such dimensions as the builder thinks fit, built into the centre of the thickness of the wall, and running along in the direction of its length.

230. Bond-timber is, however, fast falling into disuse, in view of the superior advantages of hoop-iron for binding purposes. Timber is apt to rot when imbedded in the wall, and no external evidence is given of its decay; but this objection

does not hold against the use of hoop-iron. Sir I. K. Brunel was the first who introduced this material for binding purposes, and its use has gradually extended, till it is all but universal in good constructions. Experiments have proved that brick beams have been strengthened ten times with the use of cement and iron-hoop bonds. The hoop-iron should be slightly rusted before being built in, as the adhesion of the mortar is thereby better secured. Two strips of the iron should be laid along the length of each course; where economy, however, is more consulted than efficient workmanship, one only may be used. It should be remembered that the strain the hoop-iron bond has to sustain is that of tension.

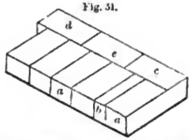
231. In carrying up walls in old English bond, the "quoins," or corners, must be commenced with a half-brick, termed a "closure" or "closer." The same must also be attended to in Flemish-bond walls; the object of this being that the bricks, as they are laid down, shall "break joint." For instance, in an old English 9-inch bond wall, in the course of stretchers, it is obvious that if the second line of stretchers, making up the thickness of the wall, started fair with the first line, all the joints would lie against each other; but by putting in a half of a brick at the end, and starting with a whole brick, all the joints of the second row, in the direction of the breadth of the course, will lie against the solid parts of the facing bricks. In fig. 50 we give the plan of the first course of a 9-inch wall in old English bond; and in fig. 51, the plan of the second course. In fig. 51, the position of the stretchers *a a a* in fig. 50 is taken by the headers *a a*; while in fig. 50, the position of the stretchers *c e d*, fig. 51, is taken by the headers *b b*. In fig. 50, by inserting the "closer" *c*, the joints of the second header *d* are carried to the solid parts of the first and second stretchers *a a*. If the closer had not been inserted, one of the joints of *d* would obviously have come to the joint of *a*. The same effect is produced by inserting the closer *b* in fig. 51. Corresponding plans of Flemish bond are shown in figs. 52 and 53; *c* and *c* being closers.

Fig. 50.



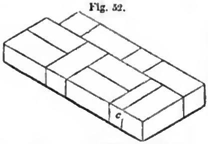
PLAN OF FIRST COURSE OF 9-INCH WALL IN OLD ENGLISH BOND—SCALE, ¼ INCH TO THE FOOT.

Fig. 51.



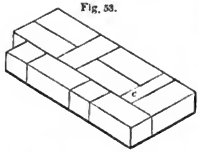
PLAN OF SECOND COURSE OF 9-INCH WALL—SCALE, ¼ INCH TO THE FOOT.

Fig. 52.



PLAN OF FIRST COURSE OF 9-INCH WALL IN FLEMISH BOND—SCALE, ¼ INCH TO THE FOOT.

Fig. 53.



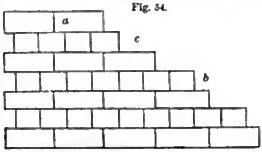
PLAN OF SECOND COURSE OF 9-INCH WALL, FLEMISH BOND—SCALE, ¼ INCH TO THE FOOT.

232. In Flemish bond the facing is generally made of a superior quality of brick, and to serve this the headers are not whole-length bricks, but are cut through. This is a practice utterly wrong; for the headers, on which depends, or should depend, the transverse strength of the wall, have no hold of the back part of the wall. The consequence is that the "backing" and "facing" separate from each other, and the whole structure becomes endangered.

233. *Walls.*—In carrying up walls, the courses should be taken up as uniformly as possible, in order to insure regular and equal settlement. If this is not attended to, and one part *a* is carried up

much higher than *b*, fig. 54, the wall will likely crack. All buildings settle or shrink; and those parts which are built up first, and allowed to settle first, will remain stationary, so that when the succeeding part is built up, its settlement will cause it to be separated from the first-built portion. All agreements should specify that no particular part is to be built up exceeding 4 feet in height. As each part is thus built up, its ends should not be made square, but the courses should terminate so as to afford a series of step-like projections, as from *b* to *c*, fig. 54, which will afford a good bond to the next-built-up portion. The layer of mortar between the bricks should not exceed a quarter of an inch in thickness; it is a sign of bad construction when thick patches of mortar are seen between the bricks. The brick should be well wetted before setting, to free it from all matter likely to prevent adhesion of the mortar. The mortar should be carefully spread over the brick, and the one to be bedded well rammed down with the trowel, or, what is better, pressed down with a rubbing motion. The joints in the face of the work should be finished off with what is called a "straight-ruled joint."

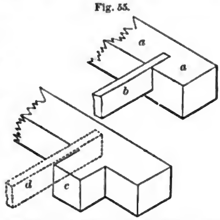
Fig. 54.



MODE OF CARRYING UP BRICK COURSES—SCALE, ½ INCH TO THE FOOT.

234. In carrying up walls, small piers, as *c*, fig. 55, should be carried up from the footings, on which to lay the flooring-joists *d*. This allows the air to circulate round the end of the joist, and tends greatly to preserve the timber. The plan of building in the ends of the joists, as the joist *b* in the wall *a a*, fig. 55, is greatly to be reprehended: the decay of the timber is hastened, and, as it decays, irregular settlement of the walls is likely to ensue. In the upper walls, as piers cannot conveniently be built, the plan illustrated in fig. 56 should be adopted, to secure the advantages of a circulation of air round the ends of the joists. In this illustration the end of the joist or beam *a* rests in an aperture or wall-box, formed by two stone or wooden slabs *b* and *b*; the width of this aperture should be greater than the breadth of the beam, so as to enable the air to circulate round its sides as well as round its end and top, as at *c*, fig. 56. For securing the ends of large girders, wall-boxes or shoes of cast-iron are built into the wall in which the ends of the girders are inserted.

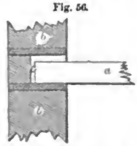
Fig. 55.



GOOD AND BAD METHODS OF SETTING FLOORING-JOISTS—SCALE, ½ INCH TO THE FOOT.

235. In the case of openings—as doors and windows—in walls, it is essential, in sound construction, to arch them over. Where the opening is narrow, good construction may, to a certain extent, be insured by the use of strong and sound timber lintels. For openings of doors and windows of the ordinary extent, the size of this lintel may be 5 inches by 4 inches, a bearing of at least 14 inches on the walls being given to it, as from *b* to *c*, fig. 57. A flat arch may be substituted for the lintel, as fig. 57. If this is used, as the whole strength depends on the mortar, it will be advisable to use cement of a good quality and hoop-iron bond. As evidence of the amazing increase of transverse strength obtained by the use of cement and hoop-iron bond, we here cite an experiment of Colonel Pasley. Brick beams were

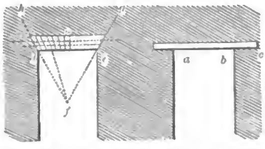
Fig. 56.



MODE OF FIXING BEAMS OF UPPER FLOORS—SCALE, ½ INCH TO THE FOOT.

made 10 feet long, 18 inches wide, 12 inches thick, of four courses, and made to rest on brick piers. The first beam was built with pure cement only; the second with pure cement and hoop-iron bond, two pieces being placed at the upper and lower joints, and one in the centre, thus ⌶–⌶; the third beam was built with mortar only. The breaking-weight was placed in the centre of the beams, between the two pieces. No. 1 (pure cement) was broken across with 498 lb.; No. 2 (pure cement and hoop-iron bond) was broken with 4723 lb.; No. 3 (mortar only) took a weight of 450 lb. only to break it.

Fig. 57.

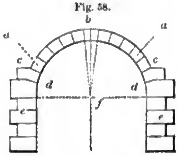


FLAT ARCH AND LINTEL—SCALE ⅛ INCH TO THE FOOT.

236. *Arches.*—To enter fully into the "theory of equilibrium" of arches, would be beyond the scope and exceed the limits of this work; we shall therefore only refer to a few forms of arches of ordinary occurrence.

237. An arch is the disposition of the building materials in a curved form, the mutual pressure of which enables them to support large weights pressing upon them. In fig. 58 the wedge-shaped blocks *a* to *a* are termed the ***voussoirs;*** the central *b* are the ***key-stones;*** the line formed by the external surface of the blocks *c* to *c*, the ***extrados;*** the line formed by their internal surface, *d* to *d*, the ***intrados***, or ***soffit***. The distance from *d* to *d* is called the ***span***, that from *f* to *b* the ***rise*** of the arch. The parts receiving the thrust of the arch *c* and *c*, or those from which the voussoirs, *a* to *a*, spring, are called the ***abutments.***

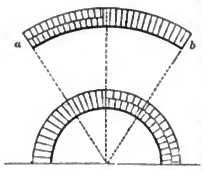
Fig. 58.



DISPOSITION OF THE PARTS OF AN ARCH—SCALE, ⅛ INCH TO THE FOOT.

238. The flat arch illustrated in fig. 57 is applicable to narrow openings, where the weight of materials over them is not great. Great care, however, should be taken to get a proper slope or bevil to the bricks, or a "skew-back," as it is termed. To proportion this, let *d e*, fig. 57, be the width of opening; from *d* and *e*, with *d e* as radius, describe arcs cutting in *f*. From *f* draw lines *f d*, *f e*, forming an equilateral triangle with *d e*; and continue them to *g* and *h*. All the joints of the bricks should converge to the point *f*. To insure good construction, the use of parallel bricks should be carefully avoided. The bricks should be rubbed to the proper shape, so that, when placed in their respective situations, the whole joints will lie close to each other. If parallel bricks are used, their upper joints naturally open. If cement is used, the work should be quickly done, as it sets rapidly; possibly the better way will be to use blue lias mortar. Arch bricks of the proper level and curvature are now made to suit arches of all sizes.

Fig. 59.



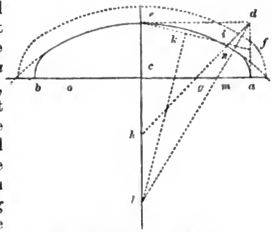
SEGMENTAL AND SEMICIRCULAR ARCHES

239. In all cases where the opening is wide, or a large amount of material is resting above it, as in the case of openings near the ground-level, circular, elliptic, or segmental arches must be constructed. Fig. 59, a segmental arch, is illustrated at *a b*, a semicircular arch at *c d*. The bricks, to insure good construction, should be carefully rubbed; but to lessen the amount of the opening of the joints at the upper ends, it is considered a good plan to divide the

depth of arch into two concentric circles or arcs. Thus a 9-inch arch may be made up of two rings of half bricks, as from *a* and *d*, fig. 59.

240. As useful to the mechanic, we here give the method of describing a semi-elliptical arch in fig. 60. Let *a b* be the span, bisect it in the point *c*, and draw a line from *e* to *l* through *c* at right angles to *a b*. Let *c e* be the rise of the arch; through *e* draw a line parallel to *a b*, and from *a* draw a line parallel to *c e*, cutting this in *d*. Bisect *a c* at *g*, and *a d* at *f*. From *d* through the point *g* draw the line *d g h*, meeting the line *e l* in *h*. Join *f* and *e*. From where the line *f e* cuts the line *d g h* at *i*, bisect the line *f e* at *k*, from which point *k* raise the perpendicular *k l*, meeting the line *e l* in *l*. Join *d* and *l*, cutting the line *a b* in *m*. From *m*, with *m a* as radius, describe the arc *a n*, and from *l*, with *l n* or *l e* as radius, describe the arc *n e*. The other half of the arch will be described by setting off the distance *a m* from *b* to *o*, and describing first an arc from *o*, with *o b* as radius, and then from this arc describing an arc to *e* from the centre *l*.

Fig. 60.

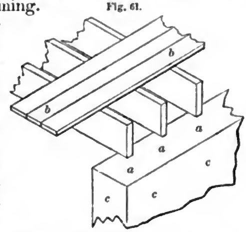


SETTING-OUT OF ELLIPTICAL ARCHES.

241. SECTION THIRD—*Construction of Timber-Framing.*—We shall now explain some of the methods of constructing timber-framing.

242. *Flooring.*—The simplest form of floor is illustrated in fig. 61, and is called the "single flooring." Where *a a a* are the joists laid on the wall *c c c*, parallel to one another, the distance should not in any case exceed 12 inches from centre to centre of joists. The flooring-planks *b b* are laid on the joists *a a a*.

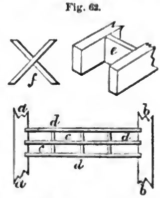
Fig. 61.



SINGLE FLOORING—SCALE ¼ INCH TO THE FOOT

243. When the walls, as *a a* and *b b*, fig. 62, are separated more than 8 feet, the joists are apt, under sudden strains — as weights hauled over the floor, people walking quickly, &c.—to bend laterally. To prevent this, struts are placed between the joists, as *c c* between the joists *d d d*. When the span of floor is wide, these struts should be placed at distances of not less than 4 feet apart. One row will do for joists, with a bearing exceeding the 8 feet; for every 4 feet of extra bearing, one row of strutting should be given. They may be formed either of pieces of thin wood, as at *e*, fig. 62, the same depth of the joists, or of two pieces crossed, as at *f*.

Fig. 62.

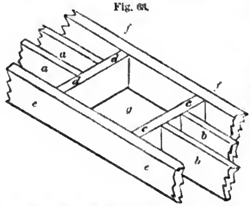


TRUSSING OF FLOORING BEAMS—SCALE, ¼ INCH TO THE FOOT

244. When the course of the joists is to be interrupted, as in fig. 63—where, for instance, a well-hole *g* is to be made, as in the floor of a barn or granary, to admit of passage from one floor to another by means of trap-stairs—the joists, as *a a*, *b b*, are supported by cross pieces *c c*, *d d*, called "trimmers" or "bridles." These again are supported by larger joists, *e e*, *f f*, which run parallel to the ordinary joists *a a*, *b b*; these larger joists are called "trimming-joists," or

"carriage-beams." The trimmers, *c c*, *d d*, must be made strong in proportion to the number of joists which they have to carry, and the scantling of the carriage-beams is proportioned to the weight which the trimmers carry. From par. 291 to 308 will be given the necessary rules for calculating the sizes of joists.

Fig. 63.

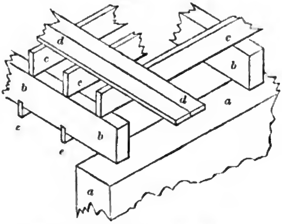


TRIMMING-JOISTS—SCALE ⅛ INCH TO THE FOOT

245. For floors of a wide span, and where more perfect work is required, as in the supporting of heavy weights, what is called "double flooring" is used. This is illustrated in fig. 64, where *b b b* represent two large joists, termed "binding joists," which are laid on the wall *a a* at each end, at distances of 10 feet apart from centre to centre. These joists support other joists, termed "bridging-joists," *c c c*, laid at right angles to *b b*. These bridging-joists are laid at distances of from 12 to 20 inches apart, and support the flooring-planks *d d*, which run parallel to the "binding-joists" *b b*. Where it is deemed in the apartments of the steading to have a "ceiling" on the under-side of the floor, what are called "ceiling-joists" should be notched into the under-side of the binding-joists, as at *e e*. The distance between these is usually set off at 12 inches.

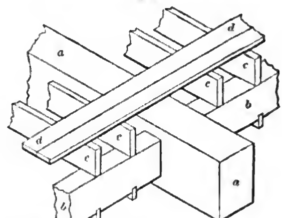
246. A still more complicated form of flooring, and one usually adopted where

Fig. 64.



DOUBLE FLOORING—SCALE ½ INCH TO THE FOOT.

Fig. 65.



DOUBLE-FRAMED FLOORING—SCALE ½ INCH TO THE FOOT

the bearing is great, is illustrated in fig. 65, and is known as the "girder," or "double-framed flooring." In this case the binding-joists *b b* are not supported at the ends by the walls, but are supported by "girders," as *a a*, which rest on the walls, and are placed generally at a distance of 10 feet apart;

Span or Bearing.	Class I. Joists.	Class II. Binders.	Class III. Girders.	Ceiling Joists.	Distance apart of Girders.	Distance apart of Binding-Joists.	Distance apart of Joists.
	W. D.	W. D.	W. D.	W. D			
6	2 × 6 in.	6 × 4 in.	...	3½ × 2 in.	10 feet apart. The bearings on wall 9 to 12 in.	4 to 6 feet apart. Bearing 4 to 6 in. on walls.	12 to 14 in. 4 to 6 in. bearing on walls.
8	2½ 7	7 4½	...	4 2¼			
10	2½ 7½	8 5	9 × 7 in.	5 2½			
12	2½ 8	9 5½	10 8	...			
14	2½ 9	10 6	11 9	...			
16	...	11 6½	12 10	...			
20	3 12	13 7½	13 11	...			
24	...	...	15 12	...			
28	...	...	16 13	...			

on the "binding-joists" *b b* the bridging-joists *c c c c* are placed, these supporting the flooring-planks *d d*.

247. Taking fig. 61 as representative of the "first class" of floors, fig. 64 of the "second," and fig. 65 of the "third," the preceding table, compiled from data given by the eminent authority Tredgold, will be useful, as showing the scantling of floors for various spans. W represents the width, and D the depth of the joists, binders, and girders.

248. The following remarks on flooring by Mr Gwilt will, we trust, be of use. First, the wall-plates—that is, the timbers which lie on the walls to receive the ends of the girders or joists—should be sufficiently strong, and of sufficient length to throw the weight upon the piers. Secondly, if it can be avoided, girders should not lie with their ends over openings, as doors or windows; but when they do, the strength of the wall-plates must be increased. To avoid the occurrence in question, it was formerly very much the practice in this country, and indeed is still partially so, to lay girders obliquely across rooms, so as to avoid openings and chimneys, the latter whereof must always be attended to. Thirdly, wall-plates and templates must be proportionately longer, as their length and the weight of the floor increase. Their scantlings will in this respect vary from $4\frac{1}{2} \times 3$ inches up to $7\frac{1}{2} \times 5$ inches. Fourthly, the timbers should always be kept rather higher—say half to three-quarters of an inch—in the middle than at the sides of an apartment, when first framed, so that the natural shrinkings and the settlements which occur in all buildings may not ultimately appear after the building is finished. Lastly, when the ends of joists or girders are supported by external walls whose height is great, the middles of such walls ought not at first to rest upon any partition-wall that does not rest higher than the floor, "but a space should (says Vitruvius, lib. vii. 1) be rather less between them, though, when all has settled, they may be brought to a bearing upon it. Neglect of this precaution will induce unequal settlements, and besides causing the floor to be thrown out of a level, will most probably fracture the corners of the room below."

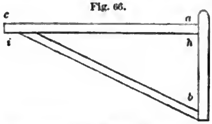
249. *Gates.*—Hitherto, it may safely be averred, very little attention has been paid to principle in the construction of field-gates; and for the truth of this we have only to look around us, where the eye of the constructive student will detect probably not more than one in a hundred of our field-gates that are not glaringly defective as pieces of constructive carpentry. Defects in point of construction are not even confined to the field-gate; we find them in many of those gates of much higher pretensions, and where, the hand of a master having been at work, we might be led to expect something like an approach to the true and simple principle. Yet how seldom does the eye experienced in directing those geometrical and dynamical principles on which alone a just and permanent system of construction depends, light upon a form that satisfies its discriminating glance.

250. *Wooden Gates.*—The essentials of a field-gate, whether of wood or iron, are a rectangular frame, consisting of the heel and head posts, and a top and bottom bar or rail, which four parts, properly connected at the angles, are rendered of an unchangeable figure by the application of one or more diagonal bars, and these diagonals should in *no case* be applied short of the whole length between any two of the opposite angles. .The upfillings, whether of rails or otherwise, as may be desired to attain any particular object, are mere accessories, and not in any way tending to the stability or durability of the fabric. In pars. 17, 18 we have pointed out the materials to be used in the construction of gates, but in the present section our illustration will have reference chiefly to those made of wood,

reserving for the succeeding section those of iron, although the principles of construction apply to structures of field-gates generally, of whatever material formed.

251. In treating of the *practical* construction of field-gates, it is perhaps unnecessary to dwell upon the strains that occur in the individual horizontal bars, because, if the principles referred to above are attended to, all cross strains in the principal joinings are avoided; and except when any extraneous force is applied, the strains are resolved by construction into those of direct compression or of tension. Thus, in fig. 66, which may represent the elements of a fly-gate applicable to a drive or thoroughfare, and opening either way, if we take the heel-post *a b* and the bar *a c* alone, and hinged in any manner at *a* and *b*; and if the bar *a c* is 10 feet long, the breadth of the heel-post at *a* 5 inches, and the parts being joined by mortise and tenon, and then suppose a load applied to the bar at *c*,—the mechanical effect of the load would be a cross strain at *h* tending to break the bar directly across, with a force equal to twenty-four times the load, exclusive of the effect of the bar itself; the bar *a c* forming here a lever of the first order, whose arm *h c* is to the arm *h a*, or the breadth of the heel-post, as 24 to 1. By increasing the number of bars we do not alter the *total* effect of the load, but simply divide it equally over the superinduced bars, supposing them to be connected with a head-post at *i*. But reverting again to the single bar *a c*, and applying to it the diagonal *b c*, we have now the triangular figure *a b c*, the parts of which being firmly connected at their points of junction, the form becomes unchangeable, and the effect of the load at *c* is instantly altered. The effect of the load at *c* is now resolvable by the parallelogram of forces into two others, the one of tension on the bar *a c*, the other of compression on the diagonal *b c*; and taking the length *a b* as a representative of the gravitating or direct effect of that load, then the tension on *a c* will be to the absolute load as the length of *a b* is to that of *a c*, and the compression on the diagonal will be as *b c* to *b a*. In this example the hinges of the gate are not shown, but in actual practice the tails of the upper hinge stretch along part of the top bar, binding it securely to the heel-post, while the bottom hinge may be made to form an abutment to the foot of the diagonal. For methods of estimating the strains, whether of compression or extension, see the section on *Principles of Framing*, from par. 156 to 191.

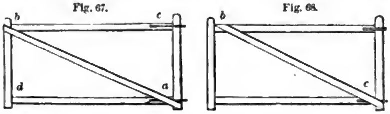
Fig. 66.



THE ELEMENTS OF A TRUSS IN A WOODEN FIELD-GATE

252. The practical insertion of the diagonal is also of some importance. Fig. 67 exhibits one mode of performing this, where *a b* is the strut half lapped upon the heel-post at bottom and upon the head-post at top: it is not an elegant mode of insertion, but it is efficient in so far that, while it acts as a strut, it binds the top of the head-post to the top bar, and prevents it from flying off by the thrust of the diagonal.

Fig. 67. Fig. 68.



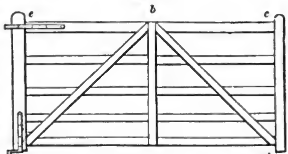
EXAMPLES OF THE APPLICATION OF A DIAGONAL

253. Fig. 68 exhibits another mode of insertion of the diagonal, which is perhaps preferable to the former: here the head of the diagonal is attached to the top bar, half lapped upon it at *b*, and notched into the lower edge as an abutment, forming a very efficient strut, the tension strain being brought entirely

upon the top-rail, which is always securely tied to the heel-post by the tails of the hinge at *c*. These examples are applicable to field-gates, where the bars are always much thinner than the heel and head posts, the latter being generally about $2\frac{1}{2}$ to 3 inches thick, and the former only $1\frac{1}{2}$ inches. In such cases the diagonal is slightly notched upon all the bars, and deeper upon the heel and head posts, where the method, fig. 67, is adopted; but in no case should the bars be notched except on the edge of the top bar, where it receives the head of the diagonal.

254. A very common form of field-gate to be seen in this country is shown in fig. 69; and applying the principles to it which we have been considering, we shall find it defective in several most essential particulars. It has a strut *a b*, but instead of extending across the entire diagonal to *c*, it stops short at the centre of the gate at *b*. The part of the top *b c* is liable to be broken off by any undue force being exerted upon it at *c*, when it is converted into a lever, whose fulcrum is supported at *b* by the end of the strut *a b*. It has also a tie *b d*, which is not only made of a wooden rail, but it does not extend across the rectangle to *e*, and in no part does it cross the strut *a b*, so as to act with it in maintaining an equilibrium of forces. The consequence in practice is, that this form of gate is very frequently fractured at the head-post *c d*, and falls to the ground at *d*.

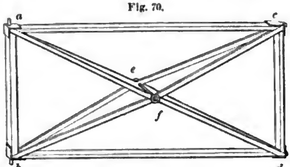
Fig. 69.



A COMMON FIELD-GATE.

255. The principle of trussing has been successfully introduced into the wooden field-gate by Sir John Orde of Kilmory in Argyllshire. Fig. 70 shows the rectangular form trussed, so as to make a compact firm structure. The heel-post *a b*, the head-post *c d*, and the upper and lower rails *a c* and *b d*, form the rectangular frame. The truss consists of four bars of wood, *a e*, *b e*, *c e*, and *de*, each of which abuts into an angle of the rectangle, and all meet at the centre of the gate *e*; where, each bar being longer than the half of a diagonal of the rectangle *a d*, they become elevated in the form of a pavilion roof. A similar truss is formed for the other face of the gate, whose apex is at *f*. Through the points *e* and *f*, the apeces of the trusses, passes the iron bolt *e f*, the head of which holds the bars at *f*; and a screw and nut upon a plate hold those at *e*; and when the screw is tightened, the trusses are brought nearer together in the centre, and their ends abut with great force against the angles of the rectangular frame at *b a c* and *d*. To resist this pressure, it is necessary to connect the posts and rails with an iron clamp at each angle of the frame. We believe that this construction of gate will admit the frame neither to bend nor twist, and it will bear any pressure of stock against its sides; but its peculiar form is attended, we think, with a practical inconvenience. The trusses rising on each side of the gate $9\frac{3}{4}$ inches above the plane of the frame, the projecting parts at *e* and *f* present an easy and ready hold for the foot of a colt, should he be disposed to amuse himself about the gate—a recreation which young horses are apt to indulge in; and the same projection will likely graze against the sides of cattle,

Fig. 70.

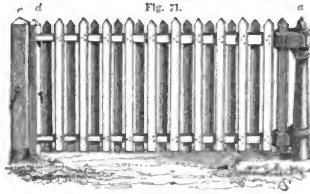


THE KILMORY WOODEN TRUSSED FIELD-GATE.

and lay hold of the harness of horses when passing through the gate. We are therefore doubtful of its utility as a common field-gate. The interior of the frame can be filled up with any light material, as wire or spars of wood. When fitted up with wooden spars, the frame costs 13s. 6d., and the posts suited for it, 13s. 6d. more.

256. A gate constructed by Mr Charles Miles, architect, London, which seems well adapted for fields, is illustrated in fig. 71. It consists of both iron and wood. It has a strong cast-iron heel-post, *a*, which is round, tapering to the top, and is batted into a large stone in the ground. At *a* is a collar of iron embracing and revolving round upon a projecting bead encircling the post. To one side of this collar is attached a socket of considerable depth, and of a form to receive into it the upper rail of the gate, which, when properly seated, the socket prevents from drooping at the head *d*. The under-rail style at *b* is in every respect fitted up in the same manner as the upper one. The head-style *d* is light, and completes the framing. The filling-up of the frame is left to choice, either in iron or wood. In the figure the filling-up consists of light wooden spars, nailed on alternately upon both sides of the upper and lower bars. Were a wooden strut introduced into the frame from the bottom rail *b* to the opposite angle at *d*, the gate would be much strengthened, though the deep hold of the sockets makes the rails much more rigid than might be expected. The receiving-post *c* is made of wood fitted into an iron socket, which is batted into a stone. The cost of the gate, without the receiving-post, is 37s. 6d.; with the post, 45s.

Fig. 71.



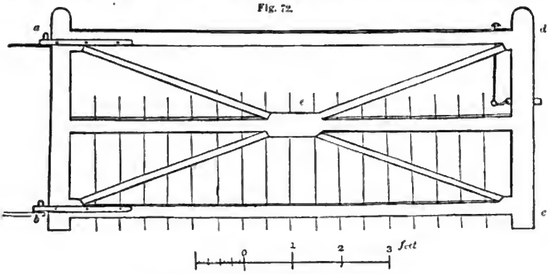
MILES' WOODEN FIELD-GATE WITH IRON HEEL-POST.

257. We have hitherto alluded only to the simplest efficient form of wooden field-gates, in the construction of which cheapness is always an object, and we have, in order to avoid confusion of ideas, restricted the description to the essential parts; the number of bars, or other means of rendering the gate a sufficient fence, is left to be filled up at discretion. In making these upfillings the maker should studiously keep in mind that no curved bars or timbers of any description should enter into the construction either for ornament, or ostensibly for use. (See par. 15, fig. 8.)

258. In the construction of wooden gates for drives or approaches, where utility is the chief object, strict attention should still be paid to the principles of construction, but a little more latitude may be admissible in point of finish and expense. For such purposes, the rails and posts of the gate should be all of one thickness, or at most, the only difference should be a gradual diminution in thickness towards the head, to lessen the effect of gravity on the hinges and gate-post: for pleasant effect, there should not be more than three horizontal rails, with two diagonals; and if it is necessary to have a closer upfilling, it should be of an upright light balustrade form. Fig. 72 is an example of this form of gate, adopted many years ago, and the originals then constructed are still good and serviceable, but it is considerably more expensive than the common field-gate. The heel-post *a b* is 5 inches broad and 3 inches thick, while the head-post *c d* may be reduced to 2¼ inches if thought advisable. The top and bottom bars are formed with abutment pieces at both ends, which are 5 inches broad, the intermediate parts being reduced to 3½ inches; the middle

bar has the same breadth, but is made up in the middle with corresponding abutments, as at *e*, and the two diagonals, of 2 inches in breadth, are inserted in four

Fig. 72.



WOODEN GATE SUITED FOR THE APPROACH TO A VILLA

pieces, exactly fitted between the abutments of the bars. The hinges are of the common double-tailed crook-and-band form, binding the top and bottom rails firmly to the heel-post, and the gate may be hung upon pillars of stone, or of wood well secured. The best balustrade for a gate of this kind is rods of iron ½ inch diameter, as in the figure, passed up through the bottom and middle bars and the diagonals, the holes for these being easily bored with an auger after the gate is formed; but a simple and cheaper balustrade is formed of light wooden spars sunk into the bars and diagonals.

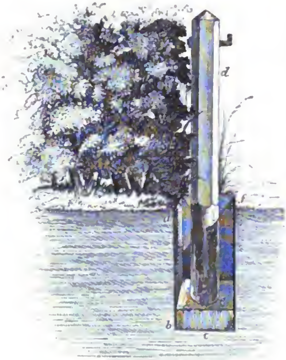
259. For all wooden gates, the method of bracing with light iron diagonals is to be preferred to wooden struts, but to be effective two diagonals must always be applied. In some cases they may pass from one angle to its opposite in one length, but in others they may be applied in four pieces, the connection at the centre of the gate being effected either by a ring of iron, in which the four ends are screwed, or by bolting the palmated ends of the four parts, two and two together, through the middle bar, as at *e*, fig. 72, one bolt securing the four ends; and in either case the rods pass through the top and bottom of the heel and head posts of the gate, and are there secured by screw-nuts. It is obvious that iron diagonals would apply in this manner to the gate, fig. 72, instead of the wooden braces from *e*.

260. Field-gates should always be made to fold back upon a fence, to open beyond the square, and not to shut of themselves. When they shut of themselves, and are not far enough pushed back when opened, they are apt to catch the wheel of a cart when passing, and to be broken, or the post to be snapped asunder by the concussion; and as self-shutting gates are all apt to be left unfastened by people who pass through them, requiring greater attention than is usually bestowed on such matters, the stock, particularly young horses, which seem to take delight to loiter about gates, might then escape from the field. Young horses are fond of rubbing their rumps against gates, to prevent which it is necessary to wattle thorns into the bars.

261. An excellent plan of fixing a hanging-post is to dig as narrow a hole as is practicable for the purpose, 3 feet deep, and at the bottom lay a flat stone of about 15 inches square and 7 or 8 inches thick, in the centre of which is cut through a hole of 8 or 9 inches in diameter, to take in the lower end of the post, dressed with the axe to fit the hole. Earth alone is then put in spadefuls into

the hole, and made firm around the post with a rammer, up to the surface of the ground, in which is sunk a stone, at the edge of the upper square face of which the iron-shod heel-post of the gate is made to rotate in a shallow hollow made to fit it. Fig. 73 shows the different parts of this mode of fastening the hanging-posts of field-gates; where *a b* is the hole into the bottom of which the stone *c* is sunk, and into this stone the end of the post *d* is inserted and secured. Water passing through the hole in the stone, the lower end of the post will be preserved; and more so by being charred or in the bark, and smeared with coal-tar: the upper part of the post at *d* will be best preserved by being planed and painted. The top of the post should always be semi-spherical, or pyramidal, to prevent the lodgment of water upon them. The earth is rammed hard into the pit *a b* to the surface of the ground, in which is sunk at *f* a stone, on which the heel-post of the gate rotates. Part of the hedge-fence of the field in which the gate is placed is shown, as also the crook above *d* on which the gate is hung.

Fig. 73.



SECOND MODE OF FASTENING THE HANGING-POST OF A FIELD-GATE.

262. Another method is in digging a hole $2\frac{1}{2}$ feet square, and of 3 feet in depth; and the post being set into it, the pit is filled with rubble masonry in mortar, packed firmly, and grouted round the post. This is no doubt a very effectual mode of fastening gate-posts—a matter not so well attended to on a farm as it ought to be; and the lime may tend to preserve the wood under ground a longer time than it would be without it; but it is expensive, and when the post has to be renewed, the masonry will have to be removed, as no new post can again be fixed so firmly in the pit as when both were put in together.

263. There is no better mode of hanging a field-gate than by crook-and-band hinge at the upper rail, and a heel-crook at the bottom of the heel-post. Both the band-hinge and the heel-crook ought to be double-tailed, to embrace both sides of the heel-post and of the upper rail. The upper-crook keeps the gate close to the upper part of the hanging-post, while the heel-crook, resting on and working in a hole made in a hard stone, supports the entire weight of the gate. A gate-post of whatever kind, which has to support the entire weight of a gate, requires to be very securely fixed into the ground; but when the gate is supported by a heel-crook, the post may be of more slender form.

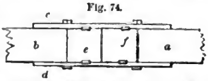
264. The simplest mode of fastening field-gates to the head-posts is to hook on a small linked chain from the stile-head of the gate to a hook in the receiving-post. No animal is able to unloosen this simple sort of fastening; but horses soon learn to unfasten almost every other sort.

265. Field-gates ought to be painted before being put to use, and they ought to receive a new coat every year, as without it they will rot in a comparatively short period of time. Iron gates must of necessity be painted, to keep them from rusting. Coal-tar does not look well as a paint, and is apt to blacken the hands and clothes after exposure for a time to the air. Many com-

positions are presented to the public notice as suitable for painting outside work, amongst which we have seen a thick black varnish, but there is nothing better than good white-lead and oil. Field-gates painted white have a lively appearance amongst the dark-green foliage of thorn hedges, and they harmonise well even with the colour of dry-stone walls.

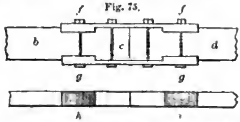
266. *Joining Timbers.*—We now proceed to illustrate the various methods in use of joining timbers together. (1.) *Joining timbers in the direction of their length.*—When timbers are to be joined in the direction of their length, when subjected to tension, the method illustrated in fig. 74 may be adopted; thus the ends of the beams *a* and *b* are squared up, and made to abut against each other; they are secured in this position by bolting together the two pieces *c* and *d*, the bolts passing through the beams *a* and *b*. This is a strong, if not the strongest, method of joining timbers under this head, although it is objected to on account of its clumsy appearance. The joint may be made stronger by notching the pieces *f f* and *g g*, as in fig. 75, or inserting flat keys into apertures made partly in the beams and partly in the pieces, as shown at *e* and *f*, fig. 74. In fig. 75, *b c d* are the two beams to be joined; *f f* and *g g* the two pieces notched in; *h* and *i* showing the plan or upper side of the notches.

Fig. 74.



JOINING TIMBERS IN THE DIRECTION OF THEIR LENGTH—SCALE, ¼ INCH TO THE FOOT.

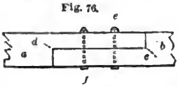
Fig. 75.



JOINING TIMBERS IN THE DIRECTION OF THEIR LENGTH—SCALE, ¼ INCH TO THE FOOT.

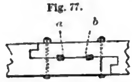
267. When the joint is so constructed that the surfaces of the two beams are flush with each other, the united beams presenting the appearance of one only, the joint is called a "scarf" joint. The simplest and the strongest form of this, known as the "half-lap joint," is shown in fig. 76; the beams to be joined being shown at *a b*, the abutting ends *c d* being square; bolts *e f* are used to

Fig. 76.



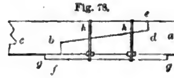
THE HALF-LAP JOINT—SCALE, ¼ INCH TO THE FOOT.

Fig. 77.



THE HALF-LAP JOINT—SCALE, ¼ INCH TO THE FOOT.

Fig. 78.



SCARF-JOINT—SCALE, ¼ INCH TO THE FOOT.

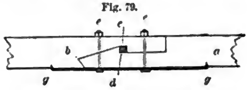
keep the parts together. Fig. 77 shows another form of "half-lap" scarf joint, *a b* being hard-wood keys. These keys should not be driven in too tightly, so as to produce any strain on the parts; all that is necessary is to bring the joints together, and then bolt together the beams firmly.

268. When the jointed beams are subjected to a cross strain, the form of "scarf" shown in fig. 78 will be found a good one. The two beams to be joined are represented by *a c*; the portion *d b* is oblique, not parallel to the surfaces of the timber as in fig. 76. The end *d e* is at right angles to the surface of the beam, the end *b f* oblique. A piece of timber *g g* is secured to the under-side by hard-wood keys, and the whole secured by iron hoops or bands *h h*.

269. Where the jointed beams are subjected to compression and extension at the same time, the form of joint should be designed to meet those strains. Fig. 79 shows a form adapted to these circumstances; *a b* are the two beams to be joined; the folding wedge or double keys *c d* serve to bring the parts together. A plate of wrought-iron *g g* is placed at the under-side, and secured by bolts *e e*.

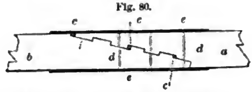
270. In fig. 80 we give a diagram illustrative of the "indented scarf-joint;" *a b* are the two beams with the surfaces of the abutting ends cut into indents

Fig. 79.



SCARF-JOINT—SCALE, ½ INCH TO THE FOOT.

Fig. 80.

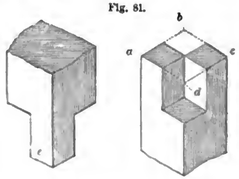


SCARF-JOINT—SCALE, ½ INCH TO THE FOOT.

and corresponding projections; a key is inserted at *c c c*; wrought-iron plates *e e* are bolted together by the bolts *d d*.

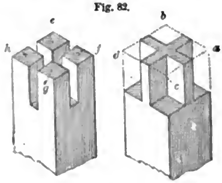
271. When two pieces of timber are to be joined vertically together in the direction of their length, to resist compression, joints, as in figs. 81 and 82, may

Fig. 81.



JOINT TO RESIST VERTICAL COMPRESSION—SCALE, 1 INCH TO THE FOOT.

Fig. 82.



JOINT TO RESIST VERTICAL COMPRESSION—SCALE, 1 INCH TO THE FOOT.

be used. In fig. 81 let *a b c d* be the end of the lower part of the beam; two square pieces are cut out at opposite corners. Let the end of the upper part of the beam be similarly cut, as at *e*, and the two placed together, so that the solid parts of the upper beam may fit into the hollow spaces of the lower beam. In fig. 82, *a b d c*, *e f g h* represent the ends of the beams to be joined. From the lower beam parts are cut at each corner, as at *a b c d*, of any depth required. The method of cutting the end of the upper beam is shown at *e f g h*; the corners being left solid, the solid parts of the lower beam go into the hollow parts in the upper beam. If there is any chance of the beams thus joined being subjected to a cross strain, plates of iron may be put at the sides, extending some distance on either side of the joints, and secured together by bolts passing through the beams, or, what will be better, by hoops passing outside.

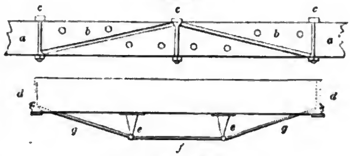
272. As regards the proportions of scarf-joints, of which we have given illustrations, Tredgold, in his valuable work on Carpentry, has given some valuable notes: these we here append. "The length of the scarf should be, if bolts are not used, in oak, ash, or elm, six times the depth of the beam—in fir, twelve times the depth of the beam. If bolts and indents are combined, the length of the scarf should be, in oak, ash, or elm, twice the depth of the beam—in fir, four times the depth. In scarfing beams to resist transverse strains, straps drawn on tight are better than bolts. The sum of the area of the bolts should not be less than one-fifth the area of the beams when a longitudinal strain is to be borne. No joint should be used in which shrinkage or expansion can tear the timbers."

273. In joining timbers, all the bearing-surfaces should be made with great accuracy, all inequalities tending to increase the strain more upon one part than another, and thus to cause rupture. The simpler the parts are the better.

274. In heavy girders of more than a foot in thickness, it is a good practice to saw them down the centre, turning the inside surfaces outward, bolting them together with pieces of thin wood between them; this enables the air to circulate freely, in addition to affording an opportunity to examine the quality and condition of the timber.

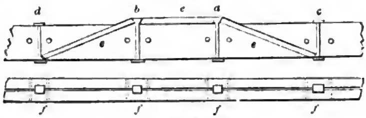
275. When the bearing of a girder exceeds 25 feet, the deflection which arises has a tendency to push out the walls in which it rests. The usual method of preventing this is to "truss" the girder. This is performed by cutting the girder in two through the centre in the direction of its length, and inserting two pieces of timber—oak is the best—inclining towards each other as in the principal rafters of a roof. The rise of these pieces is very trifling, projecting or rising very little above the beam. Fig. 83 illustrates a method of trussing a beam with wrought-iron and wood; *a a* the beam, *b b* struts or braces abutting on the wrought-iron bolts and seats *c c c*. In fig. 84 we give another method of trussing a beam after the queen-post principle, fig. 83 being on the king-post. The abutting pieces *d b a c* are of wrought-iron; the struts or braces *e e e* of wood. The two halves are bolted together by bolts and nuts, as at *f*, which is a plan showing the position of these. In fig. 83 we have another method of trussing a beam; *d d* the beam; *e e* suspension-pieces fixed to the under-side of the beam by bolts, or otherwise; *f g g* are tie-rods of wrought-iron. In fig. 85 the girder is shown trussed, with an arched piece of wrought-iron *a b c* between the two halves, the whole *d* being secured by bolts.

Fig. 83.



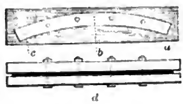
TRUSSED BEAMS.

Fig. 84.



TRUSSED BEAMS.

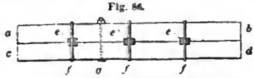
Fig. 85.



TRUSSED BEAMS.

276. A method to obtain depth in a girder, and to avoid deflection or bending, is illustrated in fig. 86, and is recommended by some as preferable to the trussed girder. Two beams of equal scantling are laid edge on, as *a b*, *c d*, and secured together by keys *e e e*, the whole being secured together by hoops of iron *f f f* driven tightly on. In place of hoops, bolts may be used, as shown at *g*, but hoops are preferable. The thickness of the keys should be equal to about half of the breadth—the total thickness of all the keys, when laid on each other, being equal to $\frac{1}{3}$ of the depth of the beam.

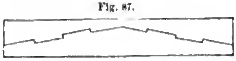
Fig. 86.



METHOD OF INCREASING DEPTH OF BEAMS.

277. In fig. 87 we illustrate another method of deepening a beam, the surfaces in contact being provided with indentations and corresponding projections, the two being well secured by bolts and nuts.

Fig. 87.

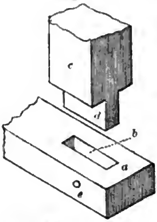


METHOD OF INCREASING DEPTH OF BEAMS.

278. (2.) *Joining timbers at right angles to each other.*—When the piece, fig.

88, is to abut vertically upon a horizontal piece *a*, the joint is made by what is called a *mortise-and-tenon joint*. The projecting piece or tongue *d* is called the *tenon*, and the slot or aperture *b* which receives it is called the *mortise*. When the piece *d* is inserted into *b*, the two are generally connected by an oak pin driven through at *e*.

Fig. 88.

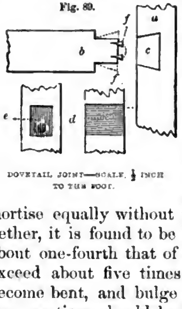


MORTISE-AND-TENON JOINT—SCALE, 1 INCH TO THE FOOT.

279. The *dovetail joint*, illustrated in fig. 89, is used when one beam abuts against another, as *b* against *a*, the piece *b* being subjected to tension. The mortise in this form is not rectangular, but horizontal, as at *c*; and the tenon is of the same form, if the piece can be driven in laterally—that is, when the mortise extends the whole way across the beam *a* as at *d*. If the tenon is to be inserted in the beam *a*, in its centre as at *e*, the tenon is made of the form as at *b*, and small oak wedges *f f* are inserted in the end of *b*; and as the tenon is driven in the mortise, the wedges *f f* are forced into and cause the tenon to expand, filling up the mortise *c*. This species of joint is called "fox-tail dovetailing."

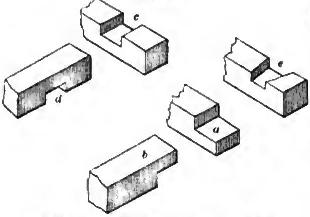
280. The following remarks from the *Encyclopædia Britannica*, article "Joinery," with reference to mortise-and-tenon joints, may be useful: "It is of the utmost importance in framing that the tenons and mortises should be truly made. After a mortise has been made with the mortise-chisel, it should be rendered perfectly even with a float, an instrument which differs from a single cut or float-file only by having larger teeth. An inexperienced workman often makes his work fit too tight in one place, and too easy in another; hence the mortise is split by driving the parts together, and the work is never firm; whereas, if the tenon fill the mortise equally without using any considerable force in driving the work together, it is found to be firm and sound. The thickness of tenons should be about one-fourth that of the framing, and the width of a tenon should never exceed about five times its thickness, otherwise, in wedging, the tenon will become bent, and bulge out of the sides of the mortise. If the rail be wide, two mortises should be made, with a space of solid wood between. In thick framing, the strength and firmness of the joint are much increased by putting a cross or feather-tongue in on each side of the tenon; these tongues are about an inch in length, and are easily put in with a plough proper for such purposes. Sometimes in thick framing a double tenon in the thickness is made, but we give the preference to a single one when tongues are put in the shoulders, as we have described; because a strong tenon is better than two weak ones, and there is less difficulty in fitting one than two." These remarks apply principally to the joints used in joinery and pattern-making, but they convey some hints useful in connection with the operations of carpentry.

Fig. 89.



DOVETAIL JOINT—SCALE, ½ INCH TO THE FOOT.

Fig. 90.

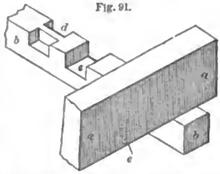


METHODS OF NOTCHING "WALL-PLATES" TOGETHER—SCALE, ½ INCH TO THE FOOT.

281. *Wall-plates* are joined at the corners by methods shown in fig. 90, half notched at the end as at *a* and *b*, or a little from the end of each, as at *c* and *d*. By this method of joining, the tendency to disconnect in either direction is prevented. A dovetail joint is sometimes used as at *e*, a corresponding tenon being made at the extremity of the other wall-plate. The joint shown at *c* and *d* is perhaps the best.

282. *Tie-beams* are joined to the wall-plates, as *a a* to *b b*, fig. 91, by the joint at *c*, the tie-beam being simply let into this. A better and more secure joint is shown at *d*, which is similar to that at *c*, with this exception, that the wood is not cut across, but a piece or feather is left in the middle: a corresponding piece *e* is cut out of the lower edge of the tie-beam, into which the feather goes.

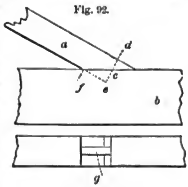
Fig. 91.



JOINING OF "TIE-BEAM" WITH WALL-PLATE—SCALE, ½ INCH TO THE FOOT.

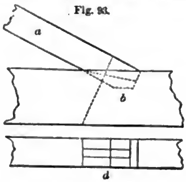
283. When one piece is oblique to the other, as in the case of the foot of the rafter butting in the end of the tie-beam, a simple joint, as in fig. 92, may be adopted—*a* is the rafter, *b* the tie-beam. The butting end *c* is at right angles to the line *e f* of the rafter. The part *d e f* is not cut out across the upper edge of the tie-beam, but a piece forming a feather (as in fig. 91 at *d*) is left as at *g*; a corresponding mortise is cut out at the lower edge of the rafter *a*, fig. 92, into which *g* fits. The tenon may be formed on the end of the rafter, and the mortise in the tie-beam; this is the usual way.

Fig. 92.



JOINING OF AN INCLINED WITH A HORIZONTAL BEAM—SCALE, ½ INCH TO THE FOOT.

Fig. 93.

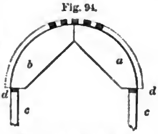


JOINING OF INCLINED BEAM WITH A HORIZONTAL BEAM—SCALE, ½ INCH TO THE FOOT.

284. A better form for the same joint is illustrated in fig. 93—*a* the rafter, *b* the tie-beam, and *d* plan of the upper edge of the tie-beam, with the mortise cut to receive the tenon *b*, formed on the end of the rafter *a*.

285. In fig. 94 we give a sketch of a simple form of centre for turning an arch over a window or door opening in a wall; *a b* are the arch timbers or ribs, two of which are used for walls of ordinary thickness. The ribs should rest on posts *c c*, between the upper ends of which and the ribs wedges should be placed; these to be driven gradually out, so as to release the ribs, and allow the arch to settle gently. The bolster-pieces *d d* are laid across the ribs at right angles to the line of the walls, and on these the bricks or building materials are laid. The curve of the ribs *a b* should be of the same radius as the desired opening in the wall, less the depth of the bolster-pieces *d*.

Fig. 94.

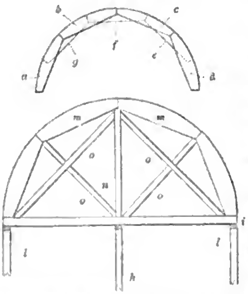


CENTRE FOR WINDOW-ARCH—SCALE, ½ INCH TO THE FOOT.

286. In fig. 95 another form of centre is shown adapted to narrow spans; each rib is composed of segmental pieces *a b c d*, of two or more thicknesses of planking. The second thickness of planking is shown at *e f g*; they are thus disposed in order to break joint with the other pieces *a b c d*. Another form of centre is also shown in fig. 95, adapted to a span where a centre-post, as *h*, can be placed to support the tie-beam *i i*, resting on two other posts *l l*. The ribs *m m* are supported by a king-post *n*, and braces *o o o o*.

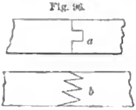
287. It does not form part of the plan of this work to describe the operations of joinery; it may, however, be serviceable to point out a few "joints" useful in the construction of implements, or of "patterns" for the parts of machines or engines. In fig. 96 we give illustrations of methods for joining flooring-timbers or planks, that at *a* being used chiefly for fir planking, that at *b* for oak. The joint at *a* is termed a "tongued and grooved" joint. In fig. 97 we show two methods of joining pieces of wood at right angles to each other. In fig. 98 we illustrate at *a* a method of joining thick timbers in the direction of their length; grooves are cut on the edges of each piece, and a hard-wood "dowel" driven into the space formed by the tongues when the two pieces are laid edge to edge. When pieces are fastened together by the joint at *b*, it is termed a "rebate" joint; it is similar to the half-lap joint, fig. 76. In pattern-making for parts of engines, as "core-boxes," &c., two pieces of wood are joined together by pins *i i*, which go into corresponding apertures, as at *j j*, fig. 98. Pieces of wood, as *c c*, are kept together by the cross piece *d*, this being provided with a feather passing into a groove made in the ends of *c c*; this is shown in the end view at *e*. The cross piece and side pieces are sometimes mitre-jointed, as at *g h h*.

Fig. 95.



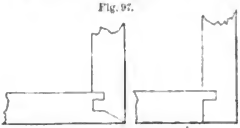
CENTRES FOR ARCHES—SCALE, $\frac{3}{8}$ INCH TO THE FOOT

Fig. 96.



JOINTS FOR FLOORING-TIMBERS—SCALE, $1\frac{1}{2}$ INCHES TO THE FOOT

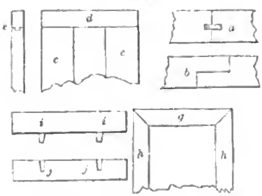
Fig. 97.



JOINTS AT RIGHT ANGLES—SCALE, $1\frac{1}{2}$ INCHES TO THE FOOT

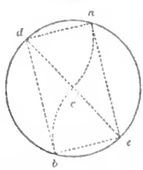
288. We here append a few notes on the cutting of timber, which may be useful; first giving a diagram of the method of cutting the *strongest beam* out of a tree, or a cylindrical balk. Let *a b*, fig. 99, be the tree, and *c* the centre; draw any diameter *e d*; from *e* and *d* as centres, with *e c* or *d c* as radius, describe arcs *b c*, *a c*; join *a d*, *d b*, *b e* and *e a* (see remarks on *Strength of Materials*, page 24, &c.)

Fig. 98.



VARIOUS FORMS OF JOINTS—SCALE, $1\frac{1}{2}$ INCHES TO THE FOOT

Fig. 99.



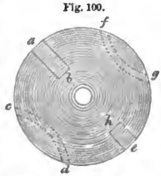
METHOD OF OBTAINING THE STRONGEST SECTION OF BEAM OUT OF A TREE—SCALE, 1 INCH TO THE FOOT.

289. In preparing timber joists, it is a good rule to have as few faces sawn as possible; a piece with one sawn face is the best and safest.

290. As to the influence which cutting timber in a peculiar way has upon its form, we extract the following from the last edition of the *Encyclopædia Britannica* (Art. "Joinery"): "It is well known that wood contracts less in proportion in diameter than it does in circumference, hence a whole tree splits in drying. Mr Knight has shown that, in consequence of this irregular contraction, a board may be cut from a tree that can scarcely be made by any

means to retain the same form and position when subjected to various degrees of heat and moisture. 'From the ash and beech,' he remarks, 'we cut some thin boards in different directions relatively to their transverse septa, so that the septa covered the middle of some of the boards at right angles, and lay nearly parallel with the surfaces of others. Both kinds were placed in a warm room under perfectly similar circumstances.'" The results of the experiments showed that while the parts which had been cut transversely to the septa, as at *c d*, fig. 100, soon became warped, concave at one side, convex at the other, the rate of contraction in drying being nearly 14 per cent in width; on the other hand, the parts cut with their surfaces nearly parallel to the septa, as *a b*, *h e*, retained with slight variation their form, and the per-centage of contraction in width was little more than 3 per cent. The same authority, in experimenting upon firs, found that a board cut like *a b* or *h e* retained its straightness, while the ash, cut like *c d* or *f g*, became hollow on one side, and convex on the other; the rate of contraction of the pieces at *c d*, *b a* being as 3.75 to 0.7 per cent. In cutting wood on this system, the pieces, as *a b* or *h e*, are found to work easily, and to present a finer surface than when the pieces are cut transverse to the septa, as *c d* or *f g*. In cutting wood, it is a good plan to "turn the stuff inside out," as it is technically termed; that is, to saw the plank down the centre, bringing the corresponding parts together, outside to outside, and reversing the circular lines of the grain.

Fig. 100.



RIGHT AND WRONG METHODS OF CUTTING TIMBER.

291. In par. 122 we gave a table of the ultimate breaking-weight, or the strain which will break a timber joist under the circumstances there mentioned; as also the greatest weight which a beam can sustain without having its elasticity destroyed. The table is also useful in calculating the dimensions of beams used, as in the case of a tie-beam, or a beam thrown across an opening, as in gateways, ports, &c.

292. To find the ultimate or breaking weight of a beam supported at both ends, and loaded in the middle: let a represent the distance in inches between the supports, b the depth of the beam, c the breadth, and s the breaking-weight of the material of which the joist is composed, this value being taken from the table in par. 122. Rule: multiply s by 4, and this by c, and by the square of b, and divide by a. Example: let the beam be 9 inches in depth by 4 in breadth or thickness, the distance between the supports 10 feet, and the material of which it is made English oak, the value of s, from the table in par. 122, being 1672—

$$\frac{1672 \times 4 \times 4 \times 81}{120} = 18057.6 \text{ lb.}$$

293. Where the beam is fixed at one end and loaded at the other, the following is the rule to ascertain the ultimate breaking-weight: let a be the depth of the beam in inches; b its breadth, also in inches; c the length of projection, also in inches, from its point of support; and s the tabular value of the material (par. 122) of which it is composed. Rule: multiply s by the square of a and the product by b, and divide by c. Example: let the beam be 8 inches deep by 5 inches thick or broad, the length it projects beyond the point of support 5 feet or 60 inches, and the material of which it is composed ash, the value of which, in the table, par. 122, is 2000; thus—

$$\frac{2000 \times 8^2 \times 5}{60} = 10666.6 \text{ lb.}$$

294. By referring to the section on *Strength of Materials*, page 24, the reader will perceive that when a weight is distributed uniformly over the surface of a beam, it will bear twice the amount applied at the centre. Beams should not be loaded with more than one-fourth of the calculated breaking-weight—in no case with more than one-third. Authorities are divided as to the exact amount or proportion; but it will be best to err on the safe side, and load beams with only one-fourth of the calculated breaking-weight.

295. In some cases a given weight is to be suspended or supported at the end of the beam fixed at one end, the deflection not to exceed a certain amount. The following is the rule to ascertain the dimensions: Let *a* represent the length of the beam from the point of support of the weight to where it is fixed in the wall, let *b* represent the breadth in inches, and *c* the load in pounds which the beam is to support, *d* the elastic strength, par. 122, of the material of which the beam is made, and *e* the deflection in inches. Rule: divide *c* the weight by *d* the elastic strength, multiplied by *b* the breadth of beam, and *e* the deflection of the elastic strength. The cube root of the quotient multiplied by *a* (the length) will give the depth of the beam in inches. Example: a beam of elm 6 inches broad, 6 feet long, from the point of fixing, is to carry a load of half a ton or 1120 lb., the deflection not to exceed quarter of an inch; the tabular value of the elastic strength of elm, par. 122, being 50:—

$$\frac{1120}{50 \times 6 \times .25} = 15 \text{ nearly}$$

cube root of $15 = 2.466 \times 6 = 15$ nearly, which is the depth of the beam in inches.

296. When the degree of deflection *a* is known, the weight *b* which the beam has to support, and the distance *c* between the two supports at the end, the dimensions of a beam to sustain the weight in the centre may then be ascertained. Rule: multiply the weight by the cube of the distance, the length in feet; divide the product by 32 times the tabular value of the elastic strength in par. 122, of the material of which the beam is to be made, multiplied into the given deflection in inches; divide the quotient by the assumed breadth, the cube root of this will be the depth in inches. Example: What are the dimensions of a beam of Riga fir, which has to support a ton weight in the centre of its length, or 2240 lb., the distance between the supports being 20 feet, and the deflection half an inch? The tabular value of the elastic strength of Riga fir is 96.2, par. 122:—

$$\frac{{}^{3}20 = 8000 \times 2240}{96.2 \times 32 \times .5} = 1164.8.$$

Assume the breadth of the beam to be 4 inches, divide the above quotient 1164.8 by this, and the quotient is 291.2, the cube root of which is 6.82 inches, the depth required.

297. Where the beam is to be square—not rectangular, as in the above cases —the fourth root of the quotient gives the side of the beam. If the beam is to be cylindrical, multiply the quotient by 1.7, and then extract the fourth root, which will be the diameter.

298. In the case of pillars or posts to sustain compression only, the following rule, with the aid of the table in par. 122, may be used to find the dimensions. Let *a* be the length of the pillar in feet; the pressure or weight which it has to support being represented by *b*, and the tabular value of the elastic strength of the material by *d*. Rule: "multiply the weight by the square of the length, and divide this product by 20 times the elastic strength,

the quotient will be the fourth power of the thickness of the side of a square beam." If the pillar is to be round, multiply the quotient by 1.7, and the fourth root will be the diameter.

299. Where the breadth of the beam is given, its length b, and the weight c it has to support, the depth of a rectangular beam may be found thus:—Rule: square the length, and multiply the weight by it; divide the product by 20 times the tabular value of the elastic strength of the material, multiplied into the breadth, the cube root of the quotient will be the least thickness required. Example: a post or pillar of oak 10 feet high, with a breadth of 4 inches, is required to sustain a pressure of 4480 lb., or 2 tons—what must be its least thickness? the tabular value of the elastic strength of oak, par. 122, is 104:—

$$\frac{10^2 = 100 \times 4480}{105 \times 20 \times 4} = 53.3, \text{ the cube root of which is 4.06 thickness of the post.}$$

300. For any post or pillar of wood to be secure, it is necessary that its height shall not exceed 10 times its diameter. The pressure on a pillar of pine, where the end butts against the grain of a lower piece, should never exceed 1000 lb. per square inch.

301. According to the experiments of Muschenbroeck, fir is better calculated for pillars or posts than oak, it being able to bear a compressile strain three times greater; oak, however, is best calculated for ties.

302. The following are calculations for determining the dimensions of the members of flooring. The distance between ordinary joists should not exceed 12 inches. Let a be the length in feet, and b the thickness. Rule: to find the depth, square the length in feet, divide this by the thickness, take the cube root of the quotient and multiply it by 2.2 when the material is pine, and by 2.3 for oak. Example: the length of pine joists is 14 feet, their thickness 4 inches—what is the depth?

$$\frac{14^2 = 196}{4} = 49, \text{ the cube root of which is } 3.65 \times 2.2 = 8.03 \text{ inches.}$$

303. Where trimmers are used as in fig. 63, an eighth of an inch should be added to the thickness of the "carriage beams" *e e*, *f f*; for every joist, as *a a*, the "trimmers" *c c*, *d d* must be made strong enough to support half the weight which the joists *a a* support.

304. To find the depth of "binding-joists," as *b b*, fig. 64, their thickness and the length in feet being given, 6 feet being the distance from centre to centre: let a be the thickness, b the length in feet, and c the multiplier for pine 3.42, and for oak 3.53. Rule: square the length, and divide it by the thickness; take the cube root of the quotient, and this, multiplied by the multiplier, will give the depth in inches. Example: the length of *pine* binders is 15 feet, the thickness 5 inches:—

$$\frac{15^2 = 225}{5} = 45, \text{ the cube root of which is } 3.55 \times 3.42 = 12 \text{ inches full.}$$

In the above formulæ, the multipliers 2.2 and 2.3 in par. 302, and 3.42 and 3.53 in par. 304, usually termed "constants," we deduced from data afforded by experiments made to ascertain the breaking-weight of beams of determined dimensions of the materials named.

305. The size of the "bridging-joists" *c c*, fig. 65, supporting the flooring-planks *d d*, will be found by the rule given in par. 304.

306. We have already given, in par. 296, a rule to estimate the ultimate breaking-weight of a beam, supported at both ends and loaded in the middle, which may be used to ascertain the scantling of girders used in the double-framed flooring illustrated in fig. 65; or the rule given in par. 302 may be used, substituting as the multiplier in 2.2 for pine the multiplier 4.2, and for oak 2.3 the multiplier 4.3.

307. A square of single flooring, fig. 61, is from 1200 to 2000 lb.; and of framed flooring, figs. 64 and 65, from 2700 to 4500 lb.

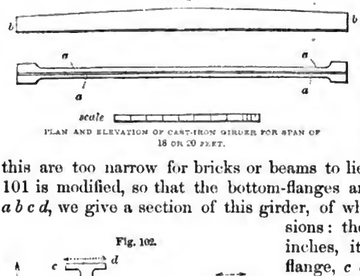
308. These results may prove useful: 46.66 cubic feet of elm, 51.49 cubic feet of beech, 47.76 cubic feet of Riga fir, 36.20 cubic feet of English oak, 66 cubic feet of Scotch fir, 47.15 cubic feet of ash, 54.55 cubic feet of red pine, 54.95 cubic feet of yellow pine, and 67.86 cubic feet of larch—weigh respectively 1 ton.

309. SECTION FOURTH—*Iron Framing.*

310. Iron, when used for the construction of flooring surfaces, is generally employed in conjunction with other materials, as wood, brickwork, concrete, &c. One obvious advantage obtained by the use of iron in the construction of framing is, the ease with which, by its means, buildings nearly if not absolutely fire-proof may be secured. We shall first describe floors composed partly of iron and partly of wood *not* fire-proof.

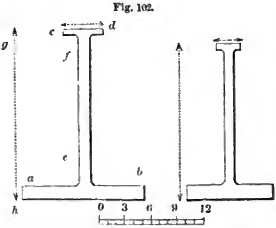
311. In figs. 18, 19, and 20, we gave illustrations of the improved form of cast-iron girder, showing sections of greatest strength. In fig. 101 we give at *b b* an elevation of a cast-iron girder, calculated for a span of 18 to 20 feet between the bearings. In the plan, fig. 19, it will be observed that the shape of the lower flange is parabolic; but as the extremities of this are too narrow for bricks or beams to lie on, the plan of the beam in fig. 101 is modified, so that the bottom-flanges are parallel, as at *a*. In fig. 102, at *a b c d*, we give a section of this girder, of which the following are the dimensions: the width of bottom flange, *a b*, 14 inches, its thickness 1⅝ inches; the top flange, *c d*, 4½ inches broad and ⅞ of an inch thick; the total depth, *g h*, 20 inches; the thickness of the rib at *e*, 1¼ inches; at *f*, 1 inch. Beams of this size, placed 9 feet apart, are calculated to support on the flooring 22 to 24 cwt. on each square yard; the weight of flooring-beams, &c., or of the arches which may be used to support the floor, being extra. In fig. 102 we also give a section of a girder where the weight per square yard is less than just stated, namely, from 12 to 13 cwt. per yard. Breadth of bottom flange 9½ inches, thickness 1½ inches; breadth of top flange 2¾ inches, thickness ⅝ inch, total depth 18 inches; thickness at section of rib corresponding to *e*, 1 inch; thickness at *f*, ⅞ of an inch.

Fig. 101.



PLAN AND ELEVATION OF CAST-IRON GIRDER FOR SPAN OF 18 OR 20 FEET.

Fig. 102.

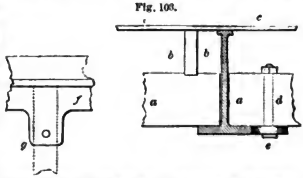


SECTION OF GIRDER FOR SPAN OF 18 OR 20 FEET.

312. In fig. 103 we illustrate a method of filling in the spaces between the

girders with the "binding-joists" *a a*, 8 inches by 5 inches; the "bridging-joists" *b b*, 6 inches by 2 inches; and the flooring-planks *c c*. Another method is shown in fig. 104, where "shoes," as *a*, are cast in the side of the girder, in which the joists *b* are laid; *c* is a front view of the shoe. Ceiling-joists, as *d*, may be suspended from the under-side of the girder by bolts and nuts, the former passing through projecting snags or brackets *e* cast into the bottom flange.

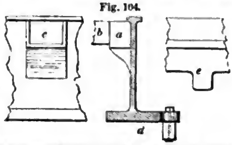
Fig. 103.



CONNECTION OF BINDING-JOISTS WITH CAST-IRON GIRDERS—SCALE, ½ INCH TO THE FOOT.

313. A very little consideration of the form of the girder now illustrated, and of the way in which it is calculated to resist any superincumbent weight that is laid upon it, will show that the method of placing the cross joists, or "binding joists," on one side of the flange, as shown in fig. 103, or in one side of the rib, as in fig. 104, is wrong. The most correct method is to place the cross joists at once on the top flanges of the girders, stretching from girder to girder. On this point Mr Fairbairn remarks: "Supporting the load on one side of the flange is wrong in principle, and, to a certain extent, injurious in practice; but that method has many conveniences, and in practice we are frequently called upon to abandon self-evident principles in order to meet the requirements of different structures. Under such circumstances, when the load is on one side of the girder, the flange should be carefully constructed, in order to bring the bearing of the cross-beam as much as possible into the centre or vertical plane of the girder." In fig. 103 we illustrate the method which Mr Fairbairn recommends to connect a wood cross-beam with the girder: small projections *e* are made in the lower flange at the places where the cross-beams *d* are to rest; bolt-holes are made in these, by which the cross-beam *d* is bolted to the flange. By this method the whole of the cross-beams and girders are united together, and the "girder will be prevented from 'canting,' as the strain has a tendency to bring the top flange inwards, and to force the top flange outwards, thus producing a lateral strain upon the girder, which would in a great measure be resisted by the bolts in the cross-beams. The best security for girders loaded in this way will, however, be good broad flanges, cast upon the top and bottom sides, in order to resist the lateral thrust of the cross-beams."

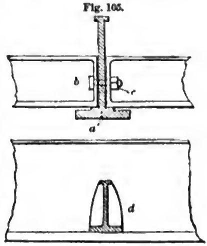
Fig. 104.



CAST-IRON GIRDERS WITH "SHOES" FOR JOISTS—SCALE, ½ INCH TO THE FOOT.

314. When the cross-beam or "binding joist" is of cast-iron, and of the same section as the girder, Mr Fairbairn recommends an arrangement to be adopted, illustrated in fig. 105, a narrow shelf *a* being cast on the side of the flange, *from one end of the girder to the other* (not merely, it is to be noted, at the places where the cross-beams occur); "this would give a sufficient bearing for the cross-beam by forming the ends, as shown in the sketch at *d*; and the bolt-holes *c* should perforate the vertical rib as near as possible to the *neutral axis* of the girder." The cross-beam is shown at *b*.

Fig. 105.

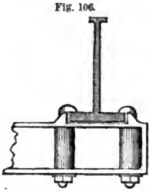


CONNECTION OF CROSS BEAMS WITH GIRDERS—SCALE, ½ INCH TO THE FOOT.

315. With reference to this plan of perforating the girder, and also of making perforations for passing through the tie-bolts, often used in trussing cast-iron girders, Mr Fairbairn says, that in "cast-iron girders," even where the hole, or rather the metal immediately surrounding the aperture, is greatly strengthened, "such a process, if not fatal, would be, to say the least of it, exceedingly injurious. I have," he continues, "decided objections to anything like perforations in cast-iron girders; and it is even with some reluctance I would have a bolt-hole through the neutral axis, unless thickened so as to compensate for the part taken out; besides, it is exceedingly objectionable to cut off the connection between the two resisting flanges of a girder, or to damage in any other way a casting of this description. There is nothing I should be more tenacious about than the cutting or boring of any part of a well-proportioned girder; and I believe there is nothing so dangerous in the hands of persons unacquainted with the laws which govern the strength of these important structures."

316. Mr Fairbairn remedies the evil arising from the use of perforated girders by the plan illustrated in fig. 106. It is of *essential importance that the bottom flange shall not be perforated,* the cross-beam being supported only by "hook-bolts." The other method is to lay the cross-beams at once upon the girders.

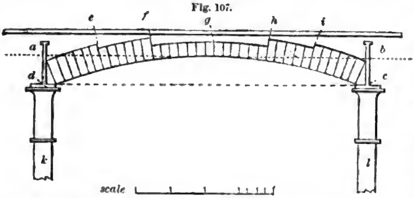
Fig. 106.



SUSPENSION OF CROSS-BEAMS FROM GIRDERS—SCALE, ¼ INCH TO THE FOOT.

317. We shall now describe the methods of making flooring fire-proof by the use of cast-iron girders and brick arches. This is illustrated in fig. 107, representing the method adopted by Mr Fairbairn during his long practice as an engineer. The cast-iron pillars *k l*, on which the girders *c d* rest, are placed at a distance of 9 feet 6 inches apart from centre to centre—the distance covered by the arch being called a "bay." A convenient length for the girders is 20 feet, as illustrated in fig. 101. In fig. 107 the arches are composed of a brick in length from *a* to *e*, or from *b* to *i*, three-quarters of a brick from *e* to *f*, or *i* to *h*, and half a brick from *f* to *g*, or *h* to *g*; the position of the tie-rod is shown at the line *a b*. "When the arches are finished, and before the centres are struck, the key-bricks, from *f* to *h*, and also all the others, are wedged between the joints with thin pieces of slate, for the purpose of equalising the bearings, to prevent settling after the centres are withdrawn. The arches being thus secured, are afterwards levelled and filled up with a concrete of lime and ashes, on which is laid the flooring of tiles or stone flagging, as the case may be." The best and safest rise for arches such as now described is 1½ inches for every foot of span.

Fig. 107.



CAST-IRON GIRDERS, PILLARS, AND BRICK ARCHES, FOR FIRE-PROOF FLOORING

318. Where tie-rods are used to truss the girders and prevent their lateral movement, it is important that they should be placed in the proper position. This practically is at the soffit of the arch, as shown by the line *a b*, fig. 107; in this position the tie-rods will perforate the "neutral axis" of the beam. The

maximum point of tension of the tie-rods is at the bottom of the flange; but this, although the safest, is not the most convenient position in practice, as the tie-rod would then stretch across the chord of the arc, as shown by the dotted line *c d*. Tie-rods should never be placed above the arch near the top of the girder. For cases where the weight to be supported is equal to 13 cwt. per square yard, the sectional area of the tie-rods should not be less than 3 square inches for every 20 feet in width of the building; where the weight to be supported is equal to 24 cwt. per square yard, the area should be increased to nearly 5 square inches.

319. As already noticed, par. 315, Mr Fairbairn objects to all perforations in girders, as in cases where tie-rods are used; he, however, has objections to the use of tie-rods on other grounds, which we here give: "In trussing a cast-iron girder, I would much rather give the strength to the girder itself than depend upon a malleable-iron truss. The two materials are widely different in character, the one being ductile, and subject to elongation under a severe tensile strain, and the other rigid and firm under compression: they seldom, if ever, agree (if I may use the expression) well together; and during the whole of my experience I have found it safer and better to keep them separate. Besides, the effect of tightening or screwing up the truss-rods has a tendency to throw increased strain upon the girder, or, *vice versa*, upon the rods themselves; in fact, an ignorant person screwing up the trusses might do serious injury without ever being aware of having done so. Altogether, I have now, and always had, an objection to trussed girders, whether composed of chains or rods: I have, therefore, no hesitation in recommending a perfectly simple and well-proportioned girder, free from encumbrances of all kinds."

320. With the pillars, cast-iron girders, and brick arches, as in fig. 107, buildings are not so safe in the event of fire as might be expected or wished for. The heat causes the pillars, &c. to yield, more especially when cold water is dashed upon them: again, should one of the arches fall, as the stability of all of them in a measure depends upon the reaction of the adjoining arches, the whole building may be endangered. In view of these and other defects of cast-iron fire-proof constructions, and the great weight of the girder, wrought-iron beams have been introduced with marked success. Mr Fairbairn, than whom no more practical authority on all matters connected with construction can be cited, thus remarks on their use:—

321. "From the increased safety and greatly increased strength of the wrought-iron beam, it appears to me to be in every respect adapted to the construction of fire-proof buildings. It offers much greater security, and is free from the risk of those accidents which not unfrequently occur with cast-iron beams, and which have created so much alarm in the public mind. . . . It now becomes a consideration of some importance to exhibit the advantages which may be gained by its introduction, on a large scale, into the building of warehouses, cotton and flax mills, and dwelling-houses, which require protection from risk, whether arising from weakness, from the employment of a dangerous material, or from fire. In these erections, it will be found exceedingly valuable, irrespectively of the sense of security which the nature of the material is sure to establish in the public mind. Impressed with these convictions, I unhesitatingly recommend its adoption to the architect and engineer, and provided the laws which govern its strength be carefully attended to, I have every reason to believe that a few examples will not only give entire confidence in its powers, but that increased experience will elicit improved conditions, and probably better forms for its application."

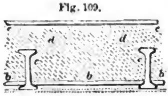
322. In fig. 108 we give a section of the "plate beam" which Mr Fairbairn most approves of. The length between the bearings for this example is 30 feet, and the breaking-weight at the centre is 27.5 tons, uniformly distributed over its surface 55 times: one-fourth or one-third of this should be the amount laid upon it. The total depth is 22 inches; the breadth of bottom flange $5\frac{1}{2}$ inches; its thickness $\frac{3}{8}$ of an inch; the breadth of upper flange $7\frac{1}{4}$ inches; and thickness $\frac{1}{2}$ an inch. The thickness of the middle plate is $\frac{5}{16}$ of an inch. As will be seen from the sketch, the beam is composed of a central plate, with angle irons riveted on each side at the upper and lower edges. There is very little difference between the cost of a girder of this kind and that of a cast-iron girder, calculated to bear the same weight; but the wrought-iron girder is only one-third of the weight of the cast-iron, and therefore costs less for carriage, and is easier erected and put in its place, besides possessing, as we have shown, the advantages of increased safety.

Fig. 108.

SECTION OF WROUGHT-IRON BEAM—SCALE ½ INCH TO THE FOOT.

323. Wrought-iron beams or joists are rolled solid after the manner of railway bars; a usual form is the I-shaped joist, as in fig. 109 at *c c*. The same figure illustrates Fox's patented method of constructing fire-proof flooring, in which the iron joists *c c* stretch across the room; *b b* are rough strips of wood bearing on the bottom flanges; these support a layer of rough mortar, indicated by the dotted lines above *b b*. The mortar is pressed down tightly so as to exude from between the joints of the strips of wood. A key or surface is thus formed to which the ceiling-plaster, &c., *a a*, adheres. Above the layer of rough mortar a bed of concrete *d d* is placed, in which is placed the flooring-tiles or cement. If boards are used for the floor, narrow strips or battens of wood *e e* are imbedded in the concrete; on these strips the boards are nailed. The iron joists *c c*, and strips of wood *b b*, are thus completely imbedded in mortar, concrete, and plaster. This system is very widely used, and forms an exceedingly strong and fire-proof floor. Where the span does not exceed 20 feet, iron joists in the length may be used; for spans exceeding this, cast or wrought iron girders will require to be used; and for spans exceeding 60 feet, columns will be required.

Fig. 109.



FIRE-PROOF FLOORING—SCALE ½ INCH TO THE FOOT.

324. We here append the dimensions of cast-iron girders, and joists or binders, for a few of the most useful spans, calculated for loads of 280 lb. per square foot of floor, this including the material resting upon the floor, as grain or machinery, and the weight of the joists and the flooring materials. Fig. 102 will illustrate the different measurements; thus *a b* is the "bottom flange," *c d* the "top flange;" *e* the "thickness of rib" at the bottom, *f* the thickness at top, *g h* total depth of girder.

325. The following are the sizes of main girders adapted to support $2\frac{1}{2}$ cwt. per square foot. A floor of 30 feet square, 900 superficial feet, supports a load of 111 tons 5 cwt. The dimensions of the girder are as follow: length, 32 feet; extreme depth, from *g* to *h*, fig. 102, 30 inches; bottom flange, *a b*, 2.4 inches in breadth, $4\frac{1}{2}$ inches thick; top flange, *c d*, 8 inches broad, $4\frac{3}{8}$ inches thick; thickness of rib at *e*, $3\frac{1}{4}$ inches; at *f*, 2 inches. For a room of 25 feet square, the floor of which, 625 feet superficial, supports nearly 81 tons; length of girder, 27 feet; breadth of bottom flange, *a b*, 21 inches, thickness $4\frac{3}{4}$ inches; breadth of top flange, *c d*, $6\frac{1}{4}$ inches, thickness $2\frac{1}{4}$ inches; depth of girder, *g h*, 24 inches; thickness of rib at *e*, $2\frac{7}{8}$; at *f*, $1\frac{3}{4}$. For a room 20 feet square, the

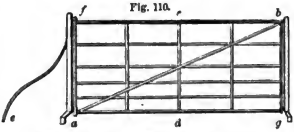
floor of which, 400 feet superficial, supports a weight of 50 tons; length of girder, 22 feet; breadth of bottom flange, *a b*, 15 inches, thickness 3 inches; breadth of top flange, *c d*, 5½ inches, thickness 1½ inches; depth of girder, *g h*, 24 inches; thickness of rib at *e*, 2 inches; at *f*, 1¼ inches. For a room of 16 feet square, the floor of which, 256 square feet, supports 28 tons, the length of the girder is 18 feet; the breadth of bottom flange, *a b*, 14 inches, its thickness 2 inches; breadth of top flange, *c d*, 4½ inches, its thickness ⅛ inch; depth of beam, *g h*, 18 inches; thickness of rib at *e*, 1¾ inches; and at *f*, 1 inch.

326. The following are the dimensions of binders or joists adapted for the foregoing cases, and still illustrated by fig. 102: For a bearing of 30 feet, with a distance of 6 feet from centre to centre of joists, the weight supported is 22½ tons, at 2½ cwt. per square foot. Length of joist 25 feet, breadth of bottom flange, *a b*, 18 inches, thickness 2¼ inches; breadth of top flange 6 inches, thickness 1⅛ inches; depth of joist, *g h*, 18 inches; thickness of rib at *e*, 1⅝; at *f*, 1¼. For a bearing of 25 feet, the distance from centre to centre of joists being 6 feet, the weight supported is nearly 19 tons. Length of joist 25 feet, breadth of bottom flange, *a b*, 18 inches, thickness 2¼; breadth of top flange, *c d*, 5¾, thickness 1½ inches; depth of joist, *g h*, 12 inches; thickness at *e*, 1⅝ inches; at *f*, 1¼. For a bearing of 16 feet, with the joists 6 feet apart from centre to centre, the weight supported is 12 tons. The length of joist is 16 feet, the breadth of flange, *a b*, 8 inches, its thickness 2 inches; the breadth of flange, *c d*, 3 inches, thickness 1 inch; depth of joist, *g h*, 12 inches; thickness of rib at *e*, 1¼; at *f*, 1 inch. For a very full table of the sizes of girders and joists for a variety of spans and depths, we would recommend the reader to Weale's *Engineer's Pocket-Book for* 1855-56 (6s.)

327. *Iron Gates.*—In paragraphs 249 to 259 we have illustrated and described several forms of wooden gates. We shall now give some figures illustrative of the application of iron to these structures.

328. In the construction of malleable-iron gates, we as frequently find malformations as in those of wood, such as placing all the bars on edge except the heel and head post, misplacing the diagonal, if single, and not unfrequently applying bars variously formed in curves and fanciful figures, to serve the purpose of the diagonals. The field-gate maker should be instructed to hold steadily in view, that there is but *one position* and form for that member of the structure that can be fully efficient, and this is, the straight bar extending from the upper angle at the heel to its opposite angle at the head-post, and, if the materials of the gate are light, to apply an antagonist diagonal crossing the first. In framing the gate, also, the top and bottom bars should be set flatways, to enable the structure to resist lateral strain from animals rubbing or pushing against it.

Fig. 110.



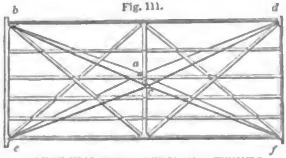
AN IRON FIELD-GATE WITH IRON POSTS AND STAY.

329. Fig. 110 gives a simple form of an iron field-gate; it consists of six rails, so arranged as to keep in lambs in the lower part of it. It is both light and strong. The fore-stile *b g* is prevented dropping by the diagonal bar *a b*, which, on being applied with its flat side, is riveted to each of the rails; and the twisting is counteracted by the top and bottom rails *f b* and *a g* being welded flat-ways to the fore and hind stiles with strong solid knees. The upright bars, as *c d*, retain each of the rails in its proper place. The gate-frame is 9 feet long and 3 feet 9 inches in height. The gate can be hung

upon wooden posts; but the iron posts, as shown in the figure, correspond better with the appearance of the gate. They are made of malleable iron, and are fastened into large stones with double bats; and the hanging-post *f a* is additionally supported by a stay *e*. The cost of this gate is 30s., and the posts 20s. more—together, 50s.—which price completes all the necessary bolts and nuts for fixing them to the stone blocks, and hanging the gate on the posts. This form of gate would probably be strengthened by the introduction of a tie stretching from *f* to *g* across the centre of the diagonal *a b*.

330. The same species of iron gate is made on the tension principle, as seen in fig. 111, where the other parts than the tension are different from those in fig. 110, in not having diagonals, as *a b*. In fig. 111 strong iron tension-wires pass through the cast-iron blocks *a* and *c*, connected together with an iron collar, in the centre of the frame. These wires are fastened by heads to the upper bar and stiles at *b* and *d*, and drawn as tight as required at the lower bar and stiles at *e* and *f*, by means of nut and screw. The cost of this gate, without the posts, is 25s.

Fig. 111.

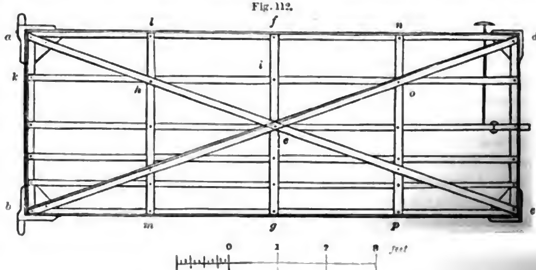


AN IRON FIELD-GATE ON THE TENSION PRINCIPLE.

331. It will be observed that the central apparatus of this gate is similar in appearance to that of the Kilmory wooden gate in fig. 70; but their mode of action is the opposite, though the effects produced are similar. In fig. 111 the wires from *a* and *c* act as ties, drawing the posts and rails towards them from the angles, and thereby giving to the entire framing a rigid structure. In fig. 70 the wooden struts from *e* and *f*, as centres, push the posts and rails outwards at the angles against the clamps, thereby also giving the framing a rigid structure.

332. One of the latest improvements in iron field-gates is the introduction of *angle-iron*, now so extensively used in boiler-making, ship-building, and other purposes. In the application of the angle-iron to the construction of gates, the fabric acquires the rigidity of a massive wooden gate, with all the tenacity and strength of the iron, while its weight is little more than that of wood. Fig. 112 is a form of gate of this construction, from a design, slightly altered, of

Fig. 112.



THE FIELD-GATE, WITH ANGLE-IRON FRAMEWORK

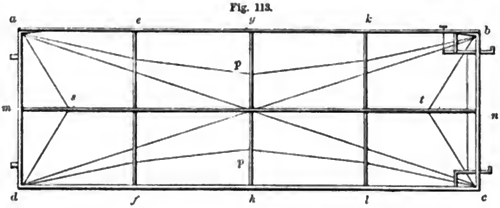
Mr William Dunlop, Edinburgh, and is manufactured by A. & G. H. Slight, Edinburgh. The external form is composed of four bars of angle-iron, measuring

$1\frac{1}{2}$ inches on each side; and to give security to the joinings at the four angles of the truss, the ends of the bars are riveted upon cast-iron corner-plates, those of the heel-post *a b* being formed with strong projecting pivots, by which the gate is hinged. Any number of interior bars may be applied to suit the objects of the gate. The figure exhibits the arrangement adapted to retain sheep and lambs. The diagonal *b d* is contrary to the general rule, for it is apparently a strut, but being a bar of angle-iron, of the same breadth as before, it possesses the stiffness of wood to resist lateral strains—and is hence properly adapted for a strut; to render the bracing complete, the antagonist diagonal *a c* is applied, and this, acting as a tie, is only a flat bar 1 inch by $\frac{1}{8}$ inch. The external frame is thus rendered unchangeable in figure by any force that may be applied to the head-post in a vertical direction, either upward or downward, short of what will fracture the gate; and the point *e*, where the diagonals cross each other at the centre of the gate, becomes also immovable in the plane of the truss; hence the perpendicular bar *f e g*, being riveted to the diagonal at *e*, acquires the same property, and by attaching all the horizontal bars to *f e g* at their several crossings, each of them is rendered permanent in its position at that point, and no force short of breaking down the gate can bend any of the parts upward or downward in the direction of the bar *f e g*, so long as this last remains attached to the crossing of the diagonals at *e*. In order to give farther support to the horizontal bars by the *principle* of construction, we have only to take a point where a diagonal crosses a bar, as at *h*, forming the opposite triangles *e h i* and *a h k*, which, when the bar and diagonal have been connected, become also immutable, and the perpendicular bar *l h m* being secured to the point *h*, and again to the different bars at their intersection with *l h m*, the whole are again rendered immovable as in the middle. The support given to the horizontal bars in the line *l h m* would have been still more complete if there had been only one intermediate bar below the middle one, as the three parts would then have met in one point, as they do at *h*, but two bars are introduced to render the gate fencible for sheep of all ages. The perpendicular bar *n o p* is applied on the same principle as seen in *l h m*, the point of support in this case being *o*. This gate would perhaps become more rigid still if the upper and lower rails *a d* and *b c* were double flanged.

333. In this construction of gates, the greatest possible amount of mutual support among the parts is obtained with a given quantity of materials; hence gates of this construction may be made lighter than any other form, where iron is the material employed, and yet have a greater amount of strength. In this example, the dimensions of the angle-iron are $1\frac{1}{2}$ inches each way, and about $\frac{1}{4}$ inch thick; all the other parts are $1\frac{1}{4}$ inches broad by $\frac{1}{8}$ inch thick, the cast-iron corner-plates being of course stouter, and the entire weight of the gate is 112 lb. It may be of use to those who make iron gates, but who have not taken time to study the first principles of their construction, to notice this further remark. Any number whatever of additional upright bars to those shown in fig. 112 would add strength or support to the horizontal bars only on the principle of superposition, or adding bar to bar, without the advantages which arise from the principle of unchangeableness to the triangle when applied in the construction of framework, whether in a simple field-gate, or in the highest branches of constructive carpentry in wood or in iron. In the one case, the stress on the parts continues to act at right angles to the bars, the direction in which they are weakest, while in the other—the principle of throwing the frame into triangles —the whole stress is thrown upon one or more parts in the direction of their length, in which position all bars and beams are strongest.

334. An example of an ingenious construction of iron gate is given in Parnell's work on road-making, which has been improved on by Dr Buist of Bombay, and described in the *Transactions of the Highland and Agricultural Society*. These gates consist of a wrought-iron external frame, which is supported by a very perfect system of bracing, with diagonal ties of iron wire, and filled up in a variety of forms with the same material. Fig. 113 represents

Fig. 113.

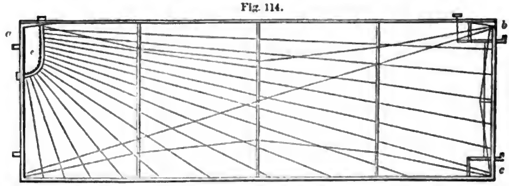


THE ELEMENTS OF THE BRACING OF A WIRE FIELD-GATE.

Dr Buist's gate with the fundamental braces and ties, which he thus describes: "The framing *a b c d* is fashioned like that of an ordinary gate; *e f*, *g h*, and *k l* are three light slips of iron parallel to the ends of the gate, and riveted to the upper and lower rails; *a p b* is a wire about the thickness of a goose-quill, fastened by a rivet at one end, and a screw and nut at the other; it passes through holes in the slips *e f*, *g h*, and *k l*, and serves as a brace to support the bar *a b*. In the same manner *d p c* serves as a brace to *d c*, while the two sides of the gate being coupled together by the slips *e f*, *g h*, and *k l*, the lower and upper rails have severally the benefit of both braces. The diagonals *a c* and *d b* keep the frame in shape, while *a s d* and *b t c* are braces to *a d* and *b c* by means of the light bar *m n*. It will be seen that all the wires and straps which act as fills-up, are either braces or supports, so that nothing can be more stiff than the gate thus completed. It weighs about 80 lb. Its dimensions are 9 feet by 3½ feet, but may be made of any size, the price varying in proportion. It may be observed, that a gate with one bolt, when shut suddenly, vibrates for some time at the fore-foot; this is obviated by two bolts coupled together near *b* and *c*, and acting simultaneously. It is also convenient for gates opening into policy-grounds, getting bolted when thrown back by means of a short stump driven into the ground, with a catch at the height of the lower bolt *c*."

335. Fig. 114 represents a gate of another construction, also by Dr Buist, filled up with wires in the form of rays from a centre. "The horizontal bar *m n*, and

Fig. 114.

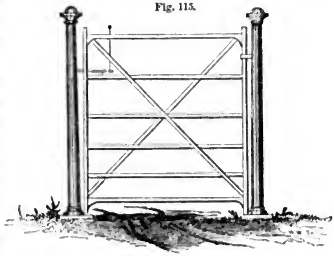


THE WIRE FIELD-GATE WITH RAYED UPFILLINGS.

the braces *a s d* and *b t c* of fig. 113," he remarks, "are here omitted as superfluous. The rays from *a* by *b* and *c* to *d*, fig. 114, consist of wires of the same thickness as before, and about 9 inches from each other. Their lower extremities are upset as nail-heads or rivets, and their upper ends are fastened with a nut and screw. For the admission of the screws a strong iron arch *e* is placed in the corner of the gate, and fastened at each end with screw-nuts; its range down the heel-post, as compared with that along the upper rail, should be as the length of the gate is to its height, which, in this example, is 18 inches down the heel-post, and 6 inches along the upper rail."* It may be here worthy of remark, as a point affecting the rigidness of this particular form of gate, that the rays of wires, being of different lengths, will be differently affected by changes of temperature, which will thereby exert an unequal action upon the many points in the lower part of the gate, and probably have a tendency to twist the gate out of the straight.

336. The wire-gates above described are admirable examples of the principles of trussed frames, and for gates. So far as that principle gives them firmness and support, they can hardly be excelled; but there is one defect attendant upon the wire upfilling, its too great tenuity, which renders the wires liable to derangement on being loaded with any cross strain, such as a person attempting to climb over the gate, and setting foot on the wires. A diagonal wire undergoing such treatment will be liable to stretch, and thereby lose its effects. Could such accidents be effectually guarded against, these gates might be regarded as almost perfect.

Fig. 115.

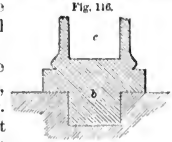


WROUGHT-IRON SIDE-GATE—SCALE ¾ INCH TO THE FOOT

337. In fig. 115 we give a form of wicket or side-gate, constructed of iron, by Messrs Young and Co. of Edinburgh. The price is from 25s. to 30s., and the posts 26s. the pair.

338. *Joinings of Iron-framing.*—For these we shall take for illustration columns and roofs, as affording a wide range of exemplification, the methods illustrated being of course applicable to all species of framing, whether of machine or otherwise.

Fig. 116.



FIXING OF CAST-IRON PILLAR—SCALE, 1 INCH TO THE FOOT.

339. And first, as to *cast-iron columns.* Where the foundation on which the column rests is good hard stone, the simplest method of fixing or bedding is shown in fig. 116, where *a* is the foundation-stone, with a socket cut into it to receive the neck *b* of the column *c*. Care must be taken to have the end of the neck perfectly flat.

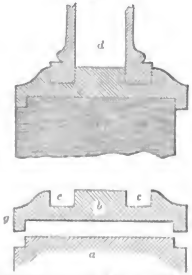
340. Where the foundation is of brick or soft stone, a cast-iron plate *g g*, fig. 117, should be let into the top of the stone *a*; the plate has a collar or projection *b*, which passes into the aperture of the pipe of the column; the solid parts of the column fit into the parts *c c*; *d* shows the pillar connected with the base.

341. The top of the pillar or column must be specially adapted to receive the girders or joists which rest upon it. A method of doing this is shown at fig. 118, where the top plate *b* is left square, and has along two of its edges snags or projections *c c*; the space between those should be wide enough to allow the girder to be inserted easily, with a little on each side to allow of expansion; *d* shows the plan of top plate. Where there are two storeys to the build-

* *Transactions of the Highland and Agricultural Society,* vol. xiv., pp. 612, 613.

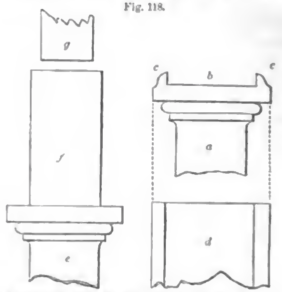
ing, and one row of columns has to rest upon the other immediately beneath, the best method to adopt is to have the neck *f* of the lower pillar *e* prolonged,

Fig. 117.



FOUNDATION-PLATE FOR CAST-IRON PILLAR—SCALE 1 INCH TO THE FOOT

Fig. 118.



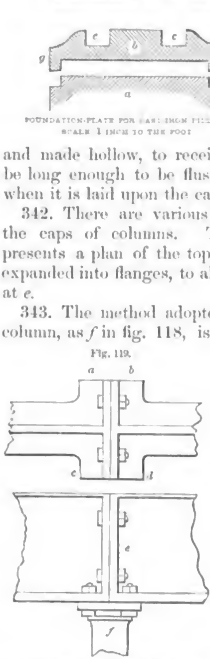
UPPER END OF PILLARS TO RECEIVE CAST-IRON BEAMS—SCALE 1 INCH TO THE FOOT.

and made hollow, to receive the end *g* of the upper pillar. The neck *f* must be long enough to be flush with or a little above the top edge of the girder, when it is laid upon the cap of the lower pillar *e*.

342. There are various methods in use to join girders together lying on the caps of columns. The simplest is illustrated in fig. 119, which represents a plan of the top of two girders, the ends *a c* and *b d* of which are expanded into flanges, to allow of bolt-holes to be made. The side view is seen at *e*.

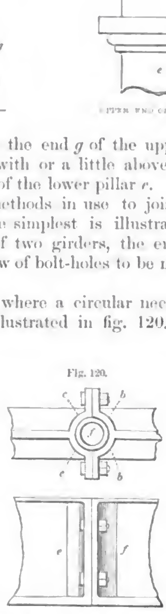
343. The method adopted where a circular neck is made to the cap of the column, as *f* in fig. 118, is illustrated in fig. 120. In this form of joint the

Fig. 119.



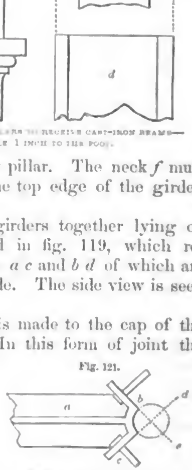
JOINING UP GIRDERS ON THE CAPS OF COLUMNS—SCALE, [illegible] INCH TO THE FOOT

Fig. 120.



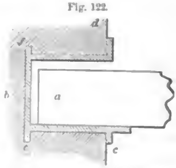
JUNCTION OF TWO GIRDERS WITH CIRCULAR NECK TO COLUMN—SCALE [illegible] INCH TO THE FOOT.

Fig. 121.



JUNCTION OF 4 GIRDERS ON CAP OF COLUMN—SCALE [illegible] INCH TO THE FOOT.

Fig. 122.



CAST-IRON SHOE FOR RECEIVING END OF GIRDER—SCALE [illegible] INCH TO THE FOOT

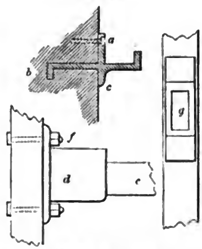
ends of the girders *b b* and *c c* are expanded into semicircular flanges, which embrace the neck *f*, as *f* and *f* in figs. 118 and 119, and are secured by bolts and nuts. The side view is shown at *e f*, fig. 120.

344. Where four girders meet on the cap of a column with neck, as at *f*, fig. 119, the ends of the girders are expanded into flanges of the form as shown in

fig. 121, at *b c*. Where four of these are put together, the ends form a figure, as shown by the dotted lines *b e*, *d c*.

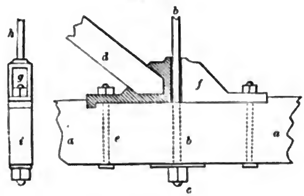
345. In fig. 122 we give a drawing of a cast-iron shoe, for the reception of the end of tie-beams or girders, as *a*. The shoe is provided with snugs *c e f d*, which act as keys, and give a secure hold in the wall. A shoe for the reception of joists which require to be bolted to wooden columns, &c., is given at *c d f* in fig. 123: this is secured by bolts and nuts as shown at *f*. In the same figure a shoe for the reception of "wall-plates," running along the wall, is shown. The wall-plate rests in the recess *a*; *c a* are projections. This may be adapted to secure to a post, &c., as the shoe *c d f*, by extending the projection *c*, as shown in form towards *b*, and passing bolts through apertures made in it;

Fig. 123.



CAST-IRON SHOES FOR "JOISTS," "WALL-PLATES"—SCALE, ½ INCH TO THE FOOT.

Fig. 124.



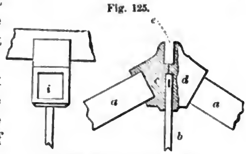
CAST-IRON SHOE FOR THE RECEPTION OF WOODEN STRUTS—SCALE, ½ INCH TO THE FOOT.

the upper bolt-hole at *a* will require to be counter-sunk, or have a recess in which the head of the bolt can go. This will allow it to lie flush with the inside of the recess, and the wall-plate to pass easily into the recess *a*. A front view is shown at *g*.

346. In composite roofs—that is, roofs composed partly of iron and partly of timber—certain parts are composed of cast-iron, as queen-bolt-heads, shoes for braces, struts or tie-beams, and purlin-boxes, &c. These we now propose to illustrate.

347. Fig. 124 illustrates a "shoe" for the reception of the feet of struts: *a a* is the wooden tie-beam, *b b* the wrought-iron king-bolt, secured by nut and washer *c*; *d* the extremity of strut or brace, butting in the shoe, the section of which is formed of the proper shape (see figs. 92, 93, page 65); *f* shows the elevation of the shoe: an aperture is cast in the solid part of the shoe, through which the king-bolt is passed. At *g h i* a front view of the shoe is shown—*g* is the part where the brace or strut enters, *h* the king-bolt, *i* part of the tie-beam.

Fig. 125.

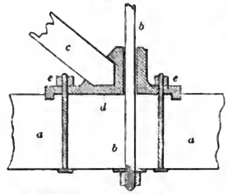


SHOES FOR KING-BOLT-HEADS—SCALE, ½ INCH TO THE FOOT.

348. Fig. 125 illustrates a form of rafter-box or shoe, for the reception and support of the principal rafters: *a a* are the upper ends of the rafters, *b* the king-bolt, *c d* the box, the side *c* of which is in section, the side *d* in elevation. An aperture is passed through the solid part to admit of the king-bolt *b* being passed through; the ridge-pole passes into the recess *e*: *i* shows a front view of the rafter-box.

349. In fig. 126 we give a drawing of a shoe for the reception of the foot of the strut and of the queen-bolt: *a a* is the tie-beam, *b b* the queen-bolt, *c* the brace or strut, *d* the shoe, secured by the bolts *e e*.

Fig. 126.

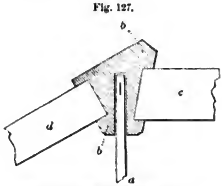


SHOE FOR QUEEN-BOLT AND STRUT—SCALE, ½ INCH TO THE FOOT.

350. Fig. 127 illustrates a queen-bolt-head "box" for the reception of straining-beam and principal rafter: *a* is the queen-bolt, the head of which is sunk into a recess in the box or shoe *b*, *c* the straining-beam, *d* the principal rafter.

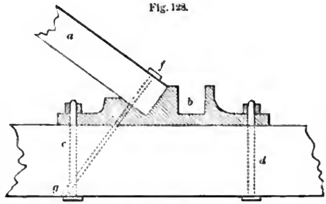
351. In fig. 128 we give a drawing of a cast-iron shoe for the reception of the end of the principal rafter and the pole-plate: *a* the rafter, *b* the recess into which the pole-plate is placed. The whole is secured to the tie-beam by bolts *c d*. Another bolt may be made to unite the foot of the principal rafter and the tie-beam, passing through in the direction of *f g*.

Fig. 127.



SHOE FOR QUEEN-BOLT AND STRUT—SCALE, ½ INCH TO THE FOOT.

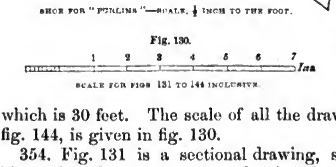
Fig. 128.



SHOE FOR FOOT OF RAFTER AND POLE-PLATE—SCALE, ½ INCH TO THE FOOT.

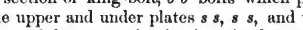
352. In fig. 129 a drawing is given of a "shoe" or box for purlins, an end view of which is given at *b b*, and a side view at *g*. The shoe *g* is passed over the upper edge of the rafter *f f* which goes into the recess *a*, and is secured by bolts and nuts at *d*; *b b*, *h* is the part receiving the purlin *c c*.

Fig. 129.



SHOE FOR "PURLINS"—SCALE, ½ INCH TO THE FOOT.

Fig. 130.



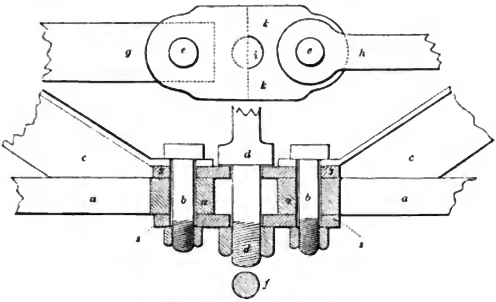
SCALE FOR FIGS 131 TO 144 INCLUSIVE.

353. We shall now illustrate methods of joining the various parts of wrought-iron roofs. These illustrations comprise the various parts of a roof on the king-post principle, the skeleton figure of which was given in fig. 33, and the span of which is 30 feet. The scale of all the drawings now to follow, from fig. 131 to fig. 144, is given in fig. 130.

354. Fig. 131 is a sectional drawing, showing connection between foot of king-bolt and struts—*a a*, *a a* the tie-bolts, *c c* the struts, *d d* the king-bolt, *f* a section of king-bolt, *b b* bolts which pass through the ends of the struts *c c*, the upper and under plates *s s*, *s s*, and the ends of the tie-bolts *a a*. A plan view of the connection is given in the upper part of the drawing: *k k* shows the form of the upper and lower plates *s s*, *s s*; *h* the termination of a tie-bolt, *g* that

of a strut. The king-bolt passes through the central aperture *i*, and the whole are secured by the bolts *b b* passing through the holes *e e*.

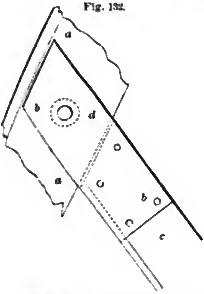
Fig. 131.



JOINING OF FEET OF STRUTS AND KING-BOLT.

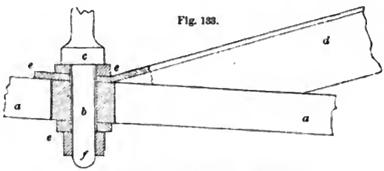
355. Fig. 132 shows the method of attaching the upper end of a strut to a rafter. In fig. 132, *a a* is the rafter, *b b* a plate (there is a corresponding plate

Fig. 132.



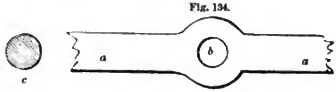
JOINING OF UPPER END OF STRUT WITH RAFTER.

Fig. 133.



JOINING OF FOOT OF QUEEN-BOLT WITH STRUT.

Fig. 134.



PLAN OF TIE-BOLT.

on the other side) attached to the rafter by a bolt passing through the plates and the rafter at *d*. The end of the strut *c* is cut off to suit the slope of the rafter as shown by the dotted lines, and passed between the two plates above described, and secured by rivets or bolts—rivets being usually employed.

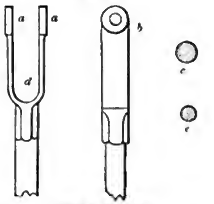
356. The method of joining the foot of strut *m* and of queen-bolt *f* with the tie-bolt *a d*, fig. 33, is illustrated in fig. 133, where *a a* is the tie-bolt, *d* the strut, *c* the lower collar of the queen-bolt, terminating in a bolt *b*, passing through the strut *d*, upper washer *e e*, tie-bolt *a a*, lower washer *e*, and secured by nut *f*. Fig. 134 shows the plan of tie-bolt corresponding to *a a*, fig. 133, with the expanded part, at the aperture *b*, through which the bolt *b*, fig. 133, passes; *c* is the section of the tie-bolt.

357. Fig. 135 illustrates the method of forming the connection between the upper end of the queen-bolt *c*, fig. 133, with the rafter *a a*, fig 132. In fig.

135, the upper part of the queen-bolt is jointed as at *d*, and provided with two eye-holes at *a a*. The plates *b b*, fig. 132, pass between the forks *a a* of the end of the queen-bolt in fig. 135; and a bolt is passed through the bolt-holes in *a a*, and the bolt-hole *d* in *b b*, fig. 132, and is secured by a nut. In fig. 135, *b* shows in view the bolt-holes at *a a*, *c* the section of the queen-bolt *f*, fig. 33 ($\frac{5}{8}$ of an inch), and *e* the section of queen-bolt *g* ($\frac{1}{2}$ inch), also fig. 33.

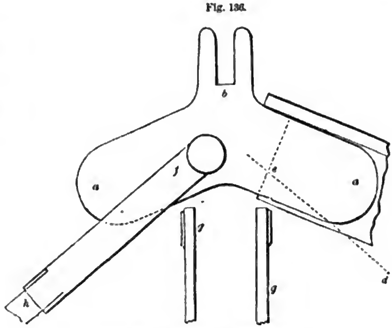
358. Fig. 136 illustrates the method of joining the upper extremities of the two rafters in *a b*, *a c*, fig. 33, the ends of which are cut off at right angles to the direction of their length, as shown by the dotted lines *e* and *d*, fig. 136. The king-

Fig. 135.



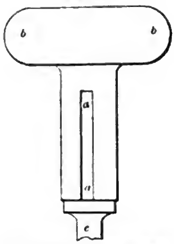
JOINT OF QUEEN-BOLT.

Fig. 136.



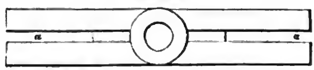
JUNCTION OF RAFTERS WITH KING-BOLT-HEAD.

Fig. 137.



END ELEVATION OF KING-BOLT-HEAD.

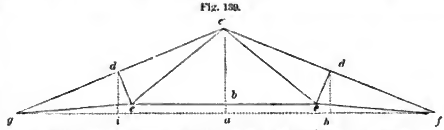
Fig. 138.



PLAN OF KING-BOLT-HEAD.

bolt-head *a a* is made of cast-iron; and space is provided between its two projecting ends, as shown at *a a*, fig. 138, into which the ends of the rafters are inserted, and secured by bolts and nuts or rivets passing through the "head" *a a*, fig. 136, and the rafters. The upper part of the head is terminated by a recess *b*, formed between two plates *b b*, fig. 137, into which the ridge-pole is placed. In the solid part of the head a core-hole is cast, into which is passed the upper end of the king-bolt *g g*; this is fixed by a key driven through slots made in the head, and the key-seat in the bolt: *h* is a tie-bolt, with its bolt-hole *f*.

Fig. 139.



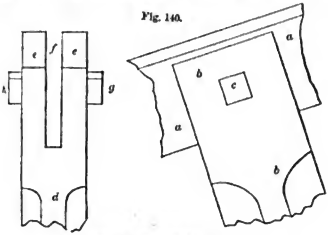
SKELETON OF IRON TRUSS FOR SPAN OF 25 FEET—SCALE, $\frac{1}{8}$ INCH TO THE FOOT.

359. Fig. 137 is an end view of king-bolt-head; *a a* the slot into which the rafter is passed, *b b* the part sustaining the ridge-pole, *c* the king-bolt. Fig. 138 is the plan of the king-bolt-head.

360. In fig. 139 we give the drawing of a 25-feet-span roof *f g*, in which the

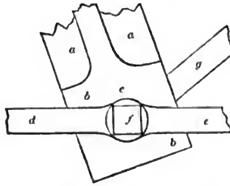
"king-bolt" at *c b* is dispensed with, and two struts, *d e*, *d e*, are used, with tie-bolts *c e*, *c e*. The dotted lines *g i a h f* and *d i*, *d h* show the position of the struts and tie-bolts before being braced up into the positions shown by the black lines.

Fig. 140.



UPPER END OF CAST-IRON STRUT.

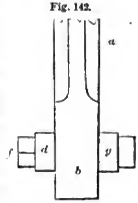
Fig. 141.



LOWER TERMINATION OF STRUT.

361. In fig. 140 we give a side and end elevation of a form of cast-iron strut adapted to the form of truss in par. 358; *a a* part of the rafter, *b b* the strut, secured by the bolt *c*. In the side elevation *d* is the lower part of the strut, *e e* the sides of the upper part, *f* the place in which the rafter *a a* is put, *g h* the bolt. In fig. 141 we give side, and in fig. 142 edge, elevations of the lower part of the strut *a a b b*, provided with a bolt-hole at *c*. The part of the tie shown at *e* corresponds to the tie *e f* in fig. 139; the part at *d*, fig. 141, to the tie *e b e* in fig. 139; the part of the tie at *g*, fig. 141, to the tie *e c*, fig. 139. The whole of these, as *d*, *e*, *g*, figs. 141, 142, are secured to the strut *a a b b* by the bolt *f*.

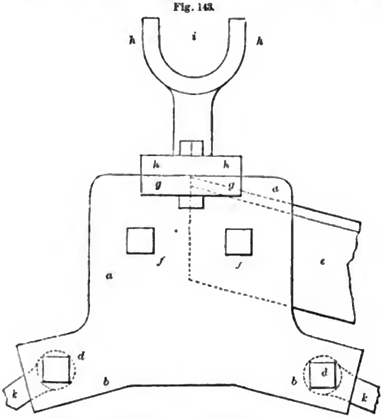
Fig. 142.



SIDE ELEVATION OF STRUT.

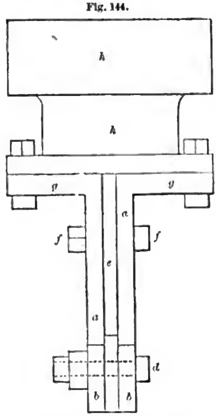
362. In fig. 143 we give a front, and in fig. 144 a side, elevation of the assemblage of rafters, ridge-pole, bracket, and ties, for a roof, as of fig. 139: *a a* the rafter-head, or box, formed of two cast-iron plates, which embrace the

Fig. 143.



JUNCTION OF RAFTERS, RIDGE-POLE, BRACKET, AND TIES.

Fig. 144.



SIDE ELEVATION OF FIG. 143.

ends e of the rafters, and are secured by bolts $f f$. They are provided with two snugs b b, to which the ties k k are bolted by the bolts d d; the brackets g g, cast to the sides of a a, support the ridge-pole box or shoe h h in the cavity i of which the ridge-pole rests.

363. We shall now give a few useful rules for calculating the dimensions of cast and wrought iron beams and columns; and first, as to *rectangular beams of cast-iron.*

364. In par. 124 we gave a table of results of experiments made to ascertain the strength, &c. of cast-iron from the principal iron-works of the kingdom. The following is the rule deduced from these experiments by Mr Fairbairn, to calculate the breaking-weight of rectangular beams of cast-iron: "Calling b and d the breadth and depth in inches, and l the distance between the supports in feet, and putting 4.5 for 4 feet 6 inches, we have the rule

$$\frac{4.5 \times b\, d^2\, s}{l} = \text{breaking-weight in pounds,}$$

the value of s being taken from the column of mean breaking-weight in lbs. in the table given in par. 124. For example, what weight would be necessary to break a bar of Lowmoor iron 2 inches broad, 3 inches deep, and 6 feet between the supports? According to the rule given above, we have $b=2$ inches, $d=3$ inches, $l=6$ feet, and s 472, from the table. Then

$$\frac{4.5 \times b\, d^2\, s}{l} = \frac{4.5 \times 2 \times 3^2 \times 472}{6} = 6372, \text{ the breaking-weight in pounds."}$$

365. In par. 146 we briefly detailed the experiments of Mr Hodgkinson to ascertain the best form of beam or girder, an illustration of which we also gave in figs. 19 and 20. The following is a simple rule for calculating the strength of beams of the strongest section: "Multiply the area of the section of the lower flange in the middle of the beam by the depth of the beam there, both in inches, and divide the product by the distance of the supports on which the beam rests, in feet. This quotient multiplied by 2.14 will give the breaking-weight."

366. The permanent load of a beam in tons can be found by multiplying the depth d of the beam in inches by the area a of the bottom flange, and dividing the product by the length l in feet between the supports. Thus, of a beam 10 inches in depth, with the area of the bottom flange 24 inches—12 inches wide and 2 inches thick—with a distance of 20 feet between the supports, the permanent load is

$$\frac{10 \times 24}{20} = 12 \text{ tons.}$$

This rule is given in Weale's *Engineer's Pocket-Book* as simpler than that given in par. 365 of Mr Hodgkinson's, and as only slightly differing (7 per cent of excess) from it in results. The weight in tons, as found by the above, 12 tons, is calculated as the permanent load distributed over the beam; the permanent load being assumed as one-fourth of the breaking-weight. Thus, by Mr Hodgkinson's rule, the breaking-weight of the beam, the dimensions of which we have given above, is as follows: a, area of bottom flange, multiplied by b, depth of beam, divided by l, the length between the supports, multiplied by 2.14; then—

$$\frac{24 \times 10}{20} = 12 \times 2.14 = 25.68 \text{ the breaking-weight in tons.}$$

The permanent load of which, taking it at one-fourth of the breaking-weight, is over 6 tons at the centre, or 12 tons uniformly distributed.

367. A rule for calculating the breaking-weight of *wrought-iron beams* of the form given in fig. 108, by Mr Fairbairn, is as follows: "Let w represent the breaking-weight in tons, a the area of the bottom flange, d the depth of the beam, and l the distance between the supports in inches; then we have

$$w = \frac{a\,d}{l}$$

For the size of the beam, as given in fig. 108—namely, area of bottom flange 5.5 inches, depth of beam 22 inches, and distance between supports 360 inches—the result is as follows: "The constant multiplier used being 75—

$$\frac{75 \times 5.5 \times 22}{360} = 25.2 \text{ tons, or } 50.4 \text{ tons distributed equally over the surface."}$$

368. The following rules are those given by Mr Hodgkinson to calculate the breaking-weight in tons of *cast-iron cylinders or columns*, fixed at the ends, and flat.

$$w = 44.16 \frac{d^{3.55}}{l^{1.7}} = \text{strength of a solid cylinder.}$$

$$w = 44.34 \frac{d^{3.55} - i^{3.55}}{l^{1.7}} = \text{strength of a hollow cylinder.}$$

w is the breaking-weight in tons; d the external, and i the internal diameter in inches, and l the length in feet. If pillars, with flat ends, be shorter than 30 times their diameter, they will be crushed as well as bent, and the value of the breaking-weight w will require to be modified by the following formula:—

$$w = \frac{w\,c}{w + \frac{3}{4}\,c}.$$

c is the weight that would crush the pillar in tons if it were so short as to be broken without flexure. To find c, multiply the area of the section of the pillar in inches by 49.

369. The reader is recommended to use a valuable table in Adcock's, *Engineer's Pocket-Book for* 1857, containing the "ultimate breaking-weight in tons of cast-iron pillars, solid and hollow," for lengths from 1 to 20 feet, at every half-foot; and for diameters, from 1 inch to 24 inches, calculated from the above formulæ. The following sizes and breaking-weights of hollow pillars of some useful sizes are deduced from the above formulæ:—

370. The breaking-weight of a pillar, 3 inches outside and 2 inches inside diameter, and 6 feet high, is 52 tons; same pillar, 10 feet high, 36 tons; 12 feet high, 26 tons; and 14 feet high, 20 tons. The breaking-weight of a pillar 4 inches outside diameter, and 3 inside, 8 feet high, is 123 tons; for a 10-feet height, 84 tons; for a 12-feet height, 62 tons; and for a 14-feet height, 47 tons. The breaking-weight of a pillar, 5 inches outside and 4 inches inside diameter, and 8 feet high, is 234 tons; 10 feet high, 160 tons; 12 feet high, 127 tons; and 14 feet high, 90 tons. The breaking-weight of a pillar 6 inches outside and 5 inches inside diameter, the height 8 feet, is 393 tons; the height 10 feet, 269 tons; 12 feet, 198 tons; and 14 feet, 152 tons. In those cases the thickness of the metal is ½ an inch. Making it 1 inch, the breaking-weights for heights of 8, 10, 12, and 14 feet, will be as follows: External diameter, 3 inches; internal, 1 inch—66 tons for 8 feet, 45 for 10, 33 for 12, and 25 for 14 feet high: External diameter, 4 inches; internal, 2 inches—174 tons for 8, 119 for 10, 87 for 12, and 63 tons for 14 feet high: External diameter, 5 inches; internal, 3 inches—356 tons

for 8, 243 for 10, 178 for 12, and 137 tons for 14 feet high: External diameter, 6 inches; internal, 4 inches—627 tons for 8, 429 for 10, 314 for 12, and 231 tons for 14 feet high. Half the breaking-weight should only be laid on pillars.

371. For the following formula for calculating the weight which a *pillar* will support, in pounds, of *solid cast-iron*, we are indebted to Mr Weale's *Engineer's Pocket-Book for* 1855-56. Let a be the constant multiplier 956^2, d the diameter in inches, and l the length in feet; then

$$\frac{a^2 \times d^4}{4 \times d^2 + 18 \times l^2} = w, \text{ the weight supported.}$$

Example: what is the weight which a solid cast-iron pillar 4 inches in diameter and 10 feet high can support?

$$\frac{956^2 \times 4^4}{4 \times 4^2 + 18 \times 10^2} = \frac{233967616}{8200} = 28532.6 \text{ pounds, or nearly } 12\tfrac{3}{4} \text{ tons.}$$

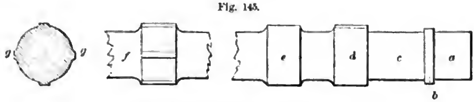
372. For *hollow cast-iron* pillars, the rule is to calculate the weight which solid pillars of diameters equal to the internal and external diameters of the hollow pillar would contain, and take the difference between them as the weight which the hollow pillar would support.

373. SECTION FIFTH—*Machine Construction.*—In this section we shall give illustrations and descriptions of the component parts of machines, their form, and the methods of "fitting" them together, concluding with some useful calculations for determining the dimensions and proportions of the various parts.

374. The following will comprise the most important parts of mechanism:—Shafts—Pedestals, Plummer-blocks, or Bearings in which Shafts work—Pulleys,—Toothed Wheels—Spur and Bevil Gearing—Eccentrics—Cams—Connecting-rods—Cranks—Clutches.

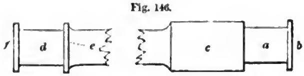
375. *Shafts* are now generally made of *cast* or *wrought iron*, rarely of *wood*. Fig. 145 represents a *cast-iron shaft* adapted for the steam-engine, of which we give a front and side elevation, in the Plate entitled *Crank Steam-Engine.* The part in which the shaft revolves, as c, is called the "neck" or "journal,"

Fig. 145.



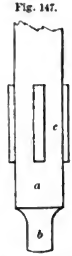
CAST-IRON SHAFT—SCALE, 1 INCH TO THE FOOT.

Fig. 146.



WROUGHT-IRON SPINDLE OR SHAFT—SCALE, 2 INCHES TO THE FOOT.

Fig. 147.



LOWER TERMINATION OF VERTICAL SHAFT—SCALE, 1 INCH TO THE FOOT

b a "collar" or "ruff," d e "bosses" on which the eccentrics are keyed. The "bosses" are sometimes made with "ribs" or projections, as at f, and at g g in section. These are made flat to act as the bed of the key, which secures the eccentric or wheel. At the part a the "crank" is keyed on.

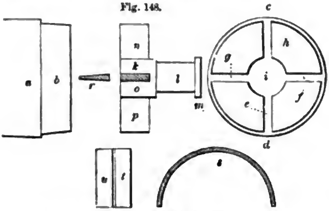
376. In fig. 146 we illustrate a *wrought-iron shaft:* when of small size, it is

termed a "spindle;" *a d* are the "necks" or "journals," *b e f* the "ruffs" or "collars," *c* a boss.

377. These shafts revolve *horizontally*, but when shafts revolve *vertically* their lower extremities run in bearings, and are made of suitable form. Fig. 147 illustrates the lower extremity of a *vertical* shaft *a*, the lower part *b* accurately turned to run in the bearing, hereafter to be described, *c* the key-seats.

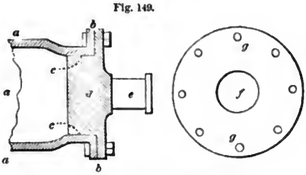
378. In heavy mill-gearing the shaft of the water-wheel is sometimes still made of *timber*. In this case the parts which revolve in their bearings must of necessity be made of iron. These parts are more frequently termed "gudgeons" than "journals." Fig. 148 illustrates a method of fixing the "gudgeon" of a timber shaft. Let *a* represent the end of the shaft in elevation, the part *b* is reduced, forming a neck or shoulder at its extremity. The end elevation of the shaft thus formed is seen at *c d*; mortises are cut in the end of the form of *e f h g*, with a central aperture *i*, the depth of which is equal to the part *b*. The "gudgeon" or "journal" *l*, with "collar" *m*, is cast along with the solid box *k*, to which four arms are cast, of which two are seen at *n p*, the four forming a

Fig. 148.



CAST-IRON GUDGEONS FOR TIMBER SHAFTS—SCALE, 1 INCH TO THE FOOT.

Fig. 149.



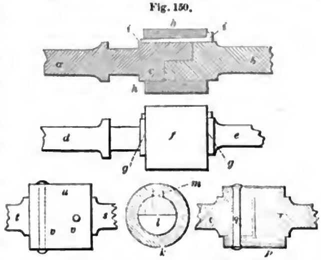
GUDGEON FOR HOLLOW CAST-IRON SHAFTS—SCALE, 1 INCH TO THE FOOT.

cross, as *e f h g*. The section of these arms is not rectangular or of equal thickness, as at *o*, but is formed, as shown at *r*, with the *back* thicker than the front edge. This is done so that when the arms of the cross are driven into the mortises *e f h g*, and iron hoops are driven and wedged over the collar *b*, the arms dovetail into the mortises; *s* shows half of one of the hoops, *t u* the half elevation of the two as they are placed on the collar *b*.

379. Heavy *cast-iron* mill or water-wheel shafts are usually cast hollow, as at *a a a*, fig. 149. The end is terminated by a flange *b b*, and the part *c c* is carefully bored; the "gudgeon" *d e* fits into *c c*, and is bolted to the flange *b b*. A front view of the outer end is shown at *f g g*: *f* is the end of the collar of the gudgeon *e*, *g g* the circular flange of the solid part *d* with the bolt-holes.

380. When shafts are required to be joined to make up certain lengths, what are called *couplings* are used to effect the junction. The forms of couplings are very numerous; we only illustrate three, the "half-lap" and the "square," and the "round box coupling." The *half-lap* is

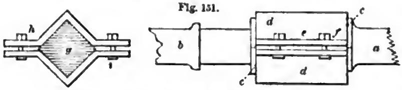
Fig. 150.



"HALF-LAP" AND "ROUND" COUPLING FOR SHAFTS—SCALE, 1 INCH TO THE FOOT.

illustrated in fig. 150: *a b* are the ends of the two shafts to be joined at *c*, with the half-lap joint (so called from its resemblance to the half-lap joint *c d* used in carpentry, fig. 76). The ends of *d e* are terminated by a boss *g g*, over which a coupling-box *f* or *h h* in section is passed to keep the shafts together, and keyed on by the key *i i*. The section is shown at *k*, *l* the shaft, *m* the key, *k* the coupling-box. The *round* coupling is shown by *p* in the same fig. 150: *n o* are the extremities of the two shafts, squared up and butting at the ends. A round "coupling-box" embraces the two, and the whole are secured together by the two pins *r* and *q* driven in at right angles. In the elevation *s t* are the ends of the shafts, *u* the coupling-box, *v v* the pins. This form is only used for small shafts or spindles, as heavy strains soon cause the pins, on which the strength of the coupling depends, to work loose. The *square* coupling is shown in fig. 151: *a b*, the two shafts, are terminated by bosses *c c*; the ends may either abut, as at *n o*, or be formed by the lap-joint at *c*, both in fig. 150. A square coupling-box *d d*, fig. 151, embraces the bosses *c c*, and are secured together by the bolts and nuts *e f*; *g* shows the section of one of the shafts, and *h i* the upper and under halves of the coupling-box.

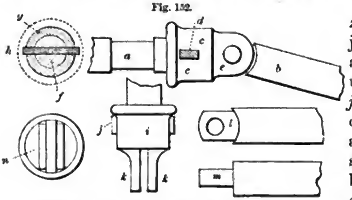
Fig. 151.



SQUARE COUPLING FOR SHAFTS—SCALE, 1 INCH TO THE FOOT.

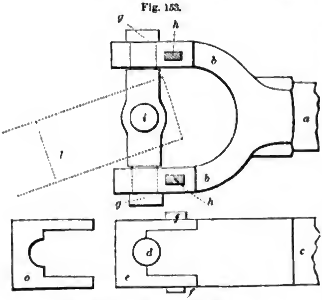
381. Where the shaft, as a *horizontal* one, *a*, fig. 152, is to be joined to another which forms an angle with it, as *b*, the coupling used is known as the "*universal joint*" or "*swing joint.*" The drawing illustrates the method adapted to small shafts, as the shafts of "chaff-cutters," &c. The box *c c* is keyed on to the bed of the shaft *a* by the key *d*. A section is shown at *f g h*: *f* is the shaft, *g* the box, and *h* the key passing through the whole; the dotted circle shows the "bead" of the box. The box *c c* is provided with two "snugs" *e* and *k k*. Into the space between these the end *l*—edge view at *m*—of the angle shaft *b* is inserted, and the joint completed by a pin or bolt passed through. A front view of the box *c c* is shown at *i*; *k k* the snugs, *j* the key. An end view of the box *c c* is seen at *n*.

Fig. 152.



SWING-JOINT FOR SMALL SHAFTS—SCALE IN FIG. 130.

Fig. 153.



UNIVERSAL JOINT—SCALE IN FIG. 130.

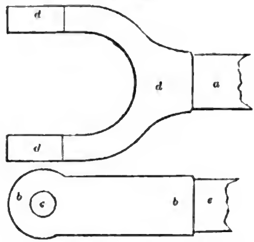
382. A form of universal joint adapted for heavier shafts, as where horse-power is communicated to a churn, straw-cutters, &c., is shown in fig. 153. The end *a* of the horizontal shaft is expanded into a fork *b b*, the extremities of which are made to embrace the "collars" *g g* of a "cross" shown in fig. 154. A side view of the shaft *a*, fig. 153, is shown at *c*; *d* the collar of the cross, *e* the

wrought-iron "cap"—separate view at *o*—keyed to the ends of the forks by the key *f f* and *h h*. The dotted lines around *l* show the position of the shaft at an angle to *a*. In fig. 154, which is a plan of the "cross," *a a* are the collars embraced by the ends *b b*, fig. 153, while *b* fig. 154, is one of those embraced by the end *i* of the angle-shaft *l*, fig. 153. In fig. 155 we give another form of universal or coupling joint, *a d d d* being the plan, *e b c b* the side view. In fig. 156

Fig. 154.

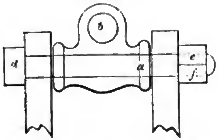
PLAN OF "CROSS" FOR UNIVERSAL JOINT —SCALE IN FIG. 130.

Fig. 155.



ANOTHER FORM OF UNIVERSAL JOINT—SCALE IN FIG. 130.

Fig. 156.

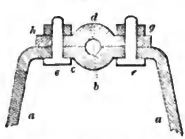


PLAN OF "CROSS"—SCALE IN FIG. 130.

we show a cross *a*; the bolt-hole is at *b*, through which a pin or bolt passes to connect the fork of the other lever, as *b b*, fig. 153. The other arm of the cross *a* is hollow, through which a bolt *d e f* passes connecting it with the ends of the fork *d d*, fig. 155, the whole secured together by the nut *f*.

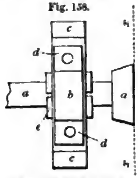
383. We now come to illustrate the *bearings* in which shafts revolve. The simplest form of a bearing is illustrated in fig. 157, where *a a* is part of the framing, curved at the part *c* to admit of a semicircular slot being made

Fig. 157.



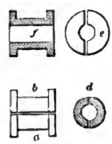
BEARING FOR SMALL SPINDLE—SCALE, 1 INCH TO THE FOOT.

Fig. 158.



PLAN OF BEARING FOR SMALL SPINDLE—SCALE, 1 INCH TO THE FOOT.

Fig. 159.



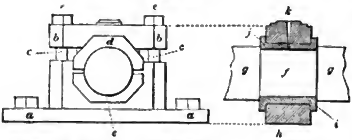
"BRASSES" OR "BUSHES" FOR BEARING FOR SMALL SPINDLE—SCALE, 1 INCH TO THE FOOT.

in its upper side, the radius of which corresponds to the diameter of the collar or neck of the shaft in *b*. The collar is embraced in its upper part by the cap *d*, which is bolted to the framing *a a* by the bolts *e f* and nuts *g h*. In fig. 158 is a top or plan view of the same; *a a* the shaft, *b* the cap, *c c* the framing, *d d* the bolts.

384. In the method illustrated in fig. 157 the shaft revolves upon iron surfaces to lessen the friction; the method in use is to make the collar of the shaft revolve on brass surfaces. These surfaces are constructed in various ways, and are termed *bushes* or *brasses*. Fig. 159 illustrates brasses adapted to the bearing in fig. 157: *a* shows a side view of the lower bush and *b* the upper, and *d* a section across the middle of both. The semicircular part of the lower bush rests on the curved part *c*, fig. 157, the upper being embraced by the cap *d*; the cap, being screwed down, keeps the bushes

always in contact with the periphery of the neck of the shaft, while the flanges at the end of the bushes prevent any lateral movement. The distance between the flanges is sufficient to allow of them passing the edges of the part *c* and the cap *d*. A sectional plan of the lower bush is shown at *f*, fig. 159, the part in which the shaft lies. An end view of the two brasses is shown at *e*, and the flanges of the brasses are shown at *e*, fig. 158.

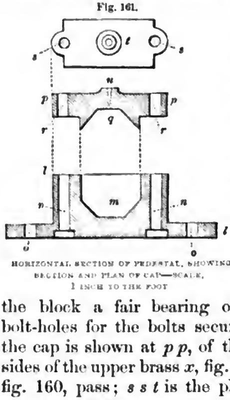
Fig. 160.



FRONT ELEVATION AND TRANSVERSE SECTION OF PEDESTAL—SCALE, 1 INCH TO THE FOOT.

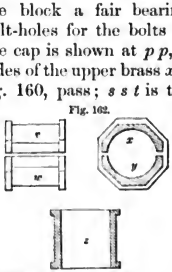
385. The method illustrated in fig. 157 is adapted for small shafts or spindles. Where long shafts are used, the bearing-surfaces are supported in what are termed *pedestals* or *plummer-blocks*. We illustrate in figs. 160, 161, 162, 163, the various parts of the pedestal in which the crank-shaft *l* revolves of the steam-engine, of which we give a front and side view in the Plate entitled *Crank Steam-Engine*. In fig. 160, *a a* is the body of the block or pedestal, secured to the entablature on which it rests by bolts and nuts, as shown at *a*; *b b*, the cap secured to the block by the bolts and nuts *c c*; *d* the upper, *e* the lower brass. In the section in same figure, *g g* is the shaft; *f* the neck or journal, corresponding to *c*, fig. 145; *h* the lower part of the block, *a a*; *i* the lower, and *j* the upper brass; *k* the cap. In fig. 161 a section through the centre of the block is given at *l l*; *m* the part with three-sided bottom, into which the lower brass *e*, fig. 160, or *y*, fig. 162, is made to fit; *n n* the bolt-holes, through which the bolts securing the cap pass. They are made with recesses at the lower part, to admit of the head of the bolts being flush with the bottom of the block, thus giving the block a fair bearing on the entablature on which it rests; *o o* the bolt-holes for the bolts securing the block to the entablature. The section of the cap is shown at *p p*, of the three-sided part fitting in to the corresponding sides of the upper brass *x*, fig. 162; *r r* the bolt-holes through which the bolts *c c*, fig. 160, pass; *s s t* is the plan of the cap. A conical aperture is made in the centre of the cap, at *t*, and which also passes through the upper brass at *k*, fig. 160; this allows of oil being poured down to lubricate the shaft *f*, as it revolves. In fig. 162 we give various views of the brasses: *v* a side-elevation of the upper, and *w* of the lower brass; *x y* corresponding sections; *z* a sectional plan of *x* or *y*: both are alike in plan.

Fig. 161.



HORIZONTAL SECTION OF PEDESTAL, SHOWING SECTION AND PLAN OF CAP—SCALE, 1 INCH TO THE FOOT

Fig. 162.

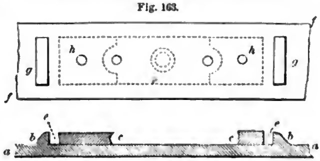


BUSHES OR BRASSES FOR PEDESTAL—SCALE, 1 INCH TO THE FOOT

386. In fig. 163 we illustrate the method of fitting the pedestal into its place on the upper side of the entablature *a a*. The bed or upper surface, as *h h*, is carefully dressed with the cold chisel, and where accurate adjustment is required, a piece of millboard bedded in whitelead may be placed, on which to rest the block; holes corresponding to those made in the entablature must be made in the millboard, to allow of the bolts passing through which secure the block to the pedestal. On the upper face of the entablature *a a* or *f f* two snugs or projec-

tions are cast, *b b* or *g g*. The distance between these is such as to admit of the body of the block being passed between, and to leave spaces, as *e e*. The block is now laid in its place, and secured by the bolts and nuts. Iron or wooden keys or wedges are then driven into the spaces *e e*; by these any degree of lateral adjustment to the block is given; vertical adjustment being obtainable by the thickness of the "packing" of millboard, &c. on which the pedestal rests. The method by which the various parts are put together is as follows: Premising that the various surfaces are brought to accurate bearings by means of chisel and file, the bolts are first passed through the holes *n n*, fig. 161, and then the body of the block, as *a a*, fig. 160, is carefully adjusted and bolted to the entablature *a a*, fig. 163; the lower brass *y*, fig. 162, is then put into the lower part of the block *m*, fig. 161; the shaft is then lifted into its place, resting on the brass *y*, and the upper side of it is embraced by the upper brass *x*, fig. 162; the cap *p p*, fig. 161, is then put on; the bolts *c c*, fig. 160, are then passed through the holes *r r*, fig. 161. The whole are then secured by the nuts *e e*, fig. 160.

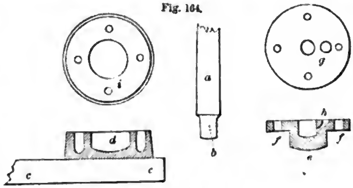
Fig. 163.



MODE OF FIXING PEDESTAL ON ENTABLATURE—SCALE, 1 INCH TO THE FOOT.

387. The bearings of *vertical* shafts are placed in what are called *steps*. A simple form of this is illustrated in fig. 164, which is the working drawing of various parts of the step adapted for the governor *t* of the steam-engine, of which we give a front and side view in Plate entitled *Crank Steam-Engine*. The lower extremities of the governor spindle is shown at *a b*; to the upper side of part of the bracket *c c* (corresponding to *u* in the Plate) a part *d* is cast. Bolt-holes are bored in this, in the positions shown in the plan as at *i*, which are tapped to receive screws. By these the bush *e f f* is secured to the part *d*; the extremity *b* of the spindle *a* runs in the hollow part of *e f f*, and the oil is passed to lubricate it through the hole *h* in the section, and *g* in the plan. The method of fitting the parts together will be obvious from the drawings, the part *e* fitting into and secured by the bolts to *d*.

Fig. 164.

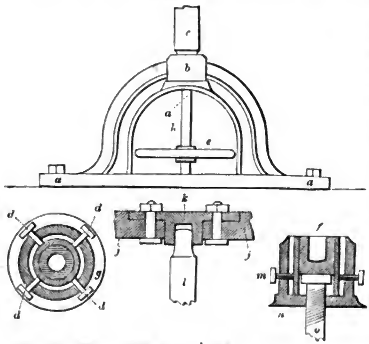


"STEP" OR BEARING FOR A VERTICAL SPINDLE—SCALE, 1 INCH TO THE FOOT.

388. Steps for heavy vertical shafts, as the shafts of millstones, require more complicated adjustment than those we have now illustrated. In fig. 165 we give views of a step for a millstone shaft; *a a a* the curved bridge or pedestal, supporting a box *b*, contains the brass bush in which the extremities of the shaft *c* revolves. This box is shown in section at *f*; this is capable of lateral adjustment by the four "set screws" *d d d d* shown in *g*, the plan of box. Another adjustment is required in millstone shafts—that is, a vertical one, so as to bring the millstones nearer to, or take them farther from each other. This is effected in various ways, one of which is shown in fig. 165. The brass bush rests on the extremity of a short lever or stud, which passes through the bottom

of the box *b* and step *a a a*, and is screwed as at *o* in section *f*; the lower end of this lever or stud moves in a bearing the sole-plate of the pedestal *a a a*. A lever-wheel *e* is keyed on to the shaft *h*, by which it is turned from right to left, and the block *b*, or *f*, in section, raised or depressed accordingly, and with it the shaft *c*.

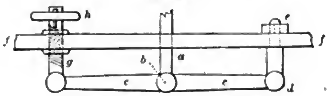
Fig 165.



STEP FOR VERTICAL SHAFT—SCALE, ½ INCH TO THE FOOT.

389. Fig. 166 shows another method of adjusting vertically the block *b* in fig. 165, of a millstone shaft: *a* is the stud on which the block rests, jointed at *b* to a lever *c c*, the end of which is connected with a stem *d*, bolted by a nut *e* to the plate *f f*, on which the step *a a*, fig. 165, rests; the screwed lever *g*, fig. 166, is jointed to the other extremity of *c c*, and is adjusted by the wheel *h*.

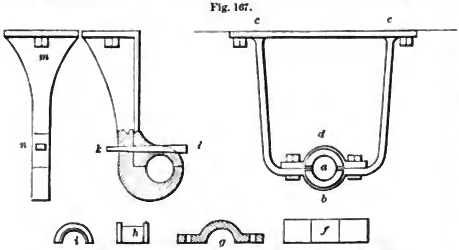
Fig. 166.



ADJUSTMENT BUSH OR STEP FOR A MILL SHAFT—SCALE ½ INCH TO THE FOOT.

390. The upper end of vertical shafts revolves in bearings, of which fig. 158 is an example; this fig., representing the upper bearing for the "governor spindle," of which *a b*, fig. 164, is the lower extremity; *a a*, fig. 158, is part of the bracket *v* of the steam-engine, of which we give a front and side view in Plate entitled *Crank Steam-Engine.* The reader will find in par. 383 a description of the various parts of this form of bearing, it only being here necessary to state that it refers to a bearing for a horizontal shaft—the same illustration serving for that of a vertical one, with this difference, that fig. 158 is lettered as an elevation, while for the vertical bearing of the spindle, *a b*, fig. 164, it is in plan. Thus by holding fig. 158 so that the line *x x* will be horizontal, it will represent the elevation of the vertical bearing, the shaft *a a* being vertical; while by reading it as printed, it represents a plan of a horizontal bearing, the same shaft *a a* being horizontal. In fig. 165 we give at *j j* an illustration of another bearing for the upper extremity of a vertical shaft *l*, the brass bush *k* being bolted to the framing *j j*.

Fig. 167.



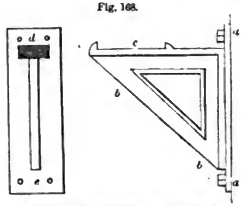
"HANGERS" OR "GALLOWS" FOR SUPPORTING SHAFTS UNDER CEILINGS—SCALE, ½ INCH TO THE FOOT.

391. When horizontal shafts are carried along under ceilings, or suspended

from part of a machine, the bearings are supported in what are termed *hangers* or *gallows*. In fig. 167 we illustrate a form of this; *a* the shaft, revolving in a brass fitted into a correspondingly curved part *b* of the hanger, which is secured to the ceiling, &c. by the bolts and nuts *c c*: *d* is the "cap," which is screwed to the part *b*; *f* is a front view, and *g* a section of the cap; *h* a front and *i* an end view of the brass or bush. The other figure to the left represents another form of hanger or gallows; it is also secured to the ceiling, &c. by bolts and nuts; the cap is secured by the key *k l*, instead of by bolts; *m* is a front view of the cap with key-seat *n*.

392. When horizontal shafts are carried along the face of a wall or part of a machine, the bearings are supported on *brackets*, of which a form is given in fig. 168; *a a* representing the line of wall, *b b* the bracket, secured to the wall by bolts and nuts. The usual form of plummer-block or pedestal is fitted in the space *c* between the two snugs. A front view of the bracket is shown at *d e*. In designing brackets and other parts of machines subjected to strains, the principles of framing, already explained from page 34, should be carefully borne in mind. Thus, in a bracket, as in fig. 168, the part *b b* supporting the table *c* should not be composed of curved lines (see par. 15).

Fig. 168.

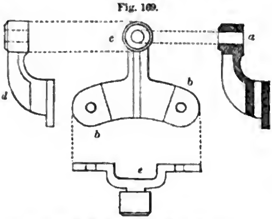


BRACKETS FOR SUPPORTING SHAFTS ALONG WALLS—SCALE, ½ INCH TO THE FOOT.

393. In fig. 169 we give three views of a *spindle-guide:* as for the rod of a slide-valve, *a* is the section, *b b* the end view, *c* the aperture in which the rod slides, *d* the side view, and *e* the plan.

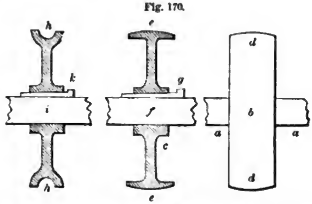
394. We shall now illustrate the methods in use by which motion is communicated from one part of a machine to another. The first of these we shall

Fig. 169.



SPINDLE-GUIDE—SCALE, 1 INCH TO THE FOOT

Fig. 170.



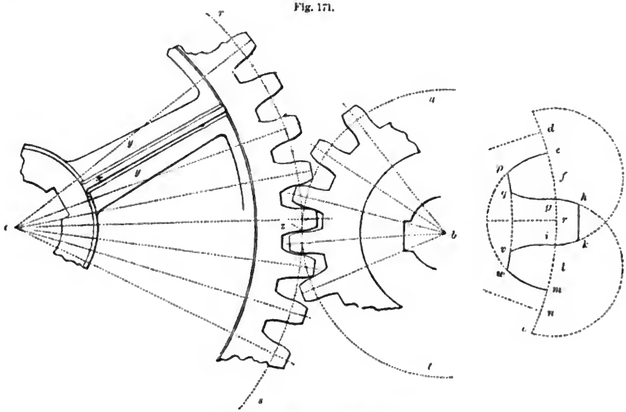
PULLEYS—SECTION AND ELEVATION—SCALE, 1 INCH TO THE FOOT.

notice are *pulleys* fixed to shafts. In fig. 170, *a a* is the shaft, *b* the pulley, *c* the central boss. A section is given at *e e*, *f* the shaft. A key-seat is cut in the boss, and a key *g* is driven in, securing the pulley on the shaft *f*. The periphery *d d* should be made convex; if made flat, the belt or driving-strap will be continually slipping off the pulley; if convex, the tendency of the belt is always to keep to the highest part, which is consequently placed in the centre of the breadth of the rim. A form of pulley with a hollow or cavity rim—used for ropes or circular belts, or wire ropes—is shown at *h*, *h h* being the cavity in which the rope runs, *i* the shaft, and *k* the key. For the forms of the arms of the pulley, see the various machines figured in the course of this work, as in the portable thrashing-machine of Messrs Garrett and Co.

395. Where *driving-belts* slip on the pulleys, a little powdered rosin strewed on their peripheries will often cause them to "bite." To obviate this risk, and to secure the transmission of the power from one point to another, "gearing-chains" are frequently employed. A notable instance of the application of these is in the Scotch thrashing-machine. In connection with the description of this machine, the reader will find illustrations of the mode of construction of the chain-gearing.

396. Motion is communicated from one point to another through the intervention of *toothed wheels.* In a system of toothed gearing, the larger wheel, as in fig. 171, is called the "spur-wheel," the smaller the "pinion." When the whole of the wheel or pinion is of one material, as iron or brass, the teeth are called "teeth;" but when the frame or body of the wheel is of iron and the teeth of wood, the latter are termed "cogs." The teeth of pinions are sometimes termed "leaves;" usually, however, the word "teeth" is used for teeth of wheels and pinions alike. The driving-wheel, which is fixed on the shaft giving the primary motion, is termed the "driver," the other the "driven" or "follower." When the teeth of two wheels are acting in contact, they are said to be in "gear," or "engaged;" when they are taken out of contact they are said to be "out of gear," or "disengaged." The methods of throwing wheels out of and into gear will be described hereafter.

Fig. 171.



MODE OF SETTING-OUT TEETH OF WHEELS.

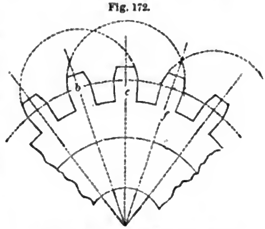
397. The line $a\ b$, fig. 171, joining the centres of two engaged wheels, is called the "line of centres;" the two dotted circles $r\ s$, $t\ u$ are termed the "pitch circles," and touch each other in the line of centres at the point z. To enable two wheels or a wheel and pinion to work together satisfactorily, it is necessary to proportion the diameters of these pitch circles to the number of teeth contained by each wheel. We shall give hereafter the rules by which these pitch circles are proportioned.

398. These pitch circles are divided into a number of equal parts, corre-

sponding to the number of teeth in the wheel or pinion; the distance between two of these divisions is termed the "pitch" of the teeth. Each division so set off comprises a tooth and a space. By space is meant the opening or interval between any two contiguous teeth.

399. In order to enable the teeth of wheels to work in contact with as little friction as possible, and in the proper ratio of velocity, it is important to decide upon the form of the tooth. To ascertain this, mathematicians and engineers have instituted the most elaborate investigations, the result of which has shown that the curve best fulfilling the conditions required in the working of *teeth* in contact is what is termed the "epicycloid" curve. Where perfect accuracy of working is required, it is advisable to set out the teeth with this curve; but as a portion of this curve resembles very closely the arc of a circle, the practice is sufficiently accurate which describes the form of teeth by portions of circles. In fig. 171 is one method of describing the form of teeth by this means. Let *r s* be the pitch circle of the "wheel," and *t u* that of the "pinion." Divide these into equal parts corresponding to the number of teeth in each, as *d*, *r*, *n*, in the smaller figure on the right; draw lines through these to the centre of the wheel and pinion, as to *a* and *b*. Let us set off the form of one tooth as of *r*. Divide each of these parts *d r* and *r n* into four equal parts, *d e f g r* and *r i l m n*. From *d*, set off *d c*, equal to one of the parts, as *d e*, and from *n*, another part *n o*. Then from *f* as a centre, with the radius *f c*, describe the semicircle *c i*, and from *l* as a centre, with the same radius, describe the semicircle *g o*; the arcs *g h* and *i k* will then form the sides of the point of the tooth *r*. Having decided on the depth of the point of the tooth *g h*, the proportion of which will be given hereafter, from *a*, the centre of the wheel, describe the arc *h k*, which gives the face of the tooth. To form the flanks of the tooth, take *d* as a centre, with the radius *d g*, describe the arc *g q*, and from *n*, as a centre, with the same radius, describe the arc *i v*. Having decided on the depth of the flanks, which we suppose to be *g q*, from *a* as a centre of the wheel with the radius *a q*, describe the arc *p q v w*: *p q* and *v w* are the spaces between the teeth. In like manner the flank of the tooth *d*, *e p*, and that of the tooth *n*, *m w*, are described from the tooth *r* as a centre. A simpler method of setting off teeth is shown in fig. 172, where the number of the teeth, the sides and depth of their points, and the depth of their flanks, are set off in a similar manner to that described, but the flanks are formed by simply drawing lines from the pitch circle at its junction with the sides of the tooth-points to the centre of the wheel. Thus are the teeth *b*, *c*, *f* formed.

Fig. 172.



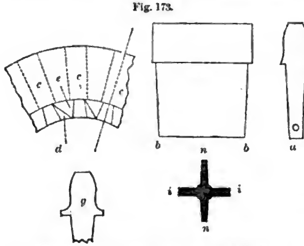
MODE OF SETTING OUT TEETH OF WHEELS.

400. In setting out the teeth, care should be taken so to proportion the number that they shall not repeatedly engage with each other. This will happen if the number of teeth in the wheel is divided by the number in the pinion without a remainder. To avoid this, let the number of the teeth of the wheel be such that it can be divided by the number in the pinion without a remainder; then add an additional tooth to the wheel. By this arrangement the wear will be equalised, as no teeth will engage twice until all the others have been in contact. The odd tooth is sometimes called the "hunting cog," or, as is more frequently stated, the number of teeth in the wheel is "prime"

to the number in the pinion. The spaces between the teeth will require to be of such a size as not only to admit of the easy insertion of the teeth of the other wheel, but to admit of a certain degree of "play." All the teeth must be of uniform size throughout, and so arranged that, as the last teeth in action cease to touch each other, the two succeeding shall come into action at the same instant.

401. Where the teeth of a *wheel* are of *wood*, those of the *pinion* being of *metal*, or *vice versâ*, the thickness of the teeth will obviously vary, in order to gain an equal strength in the teeth composed of different materials; but in all such cases the "pitch" of the teeth must remain the same. The "cogs," of wooden teeth, are made with tenons slightly tapered, and driven into mortises made in the rim of the wheel, and are secured by iron pins, as ***a b b***, fig. 173, or by double wedges, as *d e*, behind the dovetailed ends of the teeth ***c c***. A double shoulder is given to the teeth, as at *g*, which admits of a stronger tenon, and of a less weight of metal in the web of the wheel.

Fig. 173.



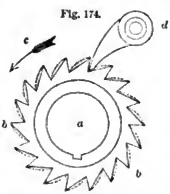
FORM OF COGS, AND SECTION OF ARM OF WHEELS.

402. The "arms" of open wheels are generally proportioned to the diameter, from six to eight being the number generally employed. They should be so arranged that the feathers, as *x x*, fig. 171, or *n n*, fig. 173, which strengthen the arms *y y*, fig. 171, should be placed, as in fig. 173, at the back of one of the teeth in wheels altogether composed of metal, and between two of the teeth where wooden cogs of beech or plane-tree are used. In fig. 173, *n n*, *i i* shows a section of the arm of a wheel. When pinions are small, arms are dispensed with, and the central part cast solid.

403. For ample instructions as to the construction of patterns of toothed wheels, we refer the reader to parts 5 and 6, 1s. each, of the *Practical Draughtsman's Book of Industrial Design*, published by Longman and Co. of London. We do not deem it necessary to give these drawings, as toothed wheels of all pitches and diameters usually employed are kept in stock by many ironfounders, and can be bought cheaper than they can be made.

404. In fig. 174 we give a sketch of a *ratchet-wheel and pawl* used in various machines, as windlasses, &c. The ratchet-wheel ***b b*** is keyed on to the shaft *a*, and is supposed to be revolving in the direction of the arrow ***c***. The pawl or click is jointed at its upper end to a stud ***d*** fixed in part of the framing of the machine. As the wheel revolves, the end of the click passes over the face of the tooth, and drops into the space between each tooth, as in the drawing. Should the wheel ***b b*** have a tendency to revolve in the wrong direction, the end of the pawl catches against the shoulder of the teeth of the wheel, and prevents it from turning round.

Fig. 174.

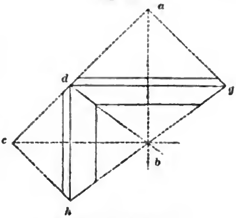


RATCHET-WHEEL AND PAWL OR CLICK.
¼ FULL SIZE.

405. Where toothed gearing is used to communicate motion from one shaft to another, the direction of which is not in the same plane, but at right angles, &c. to each other, the form of wheels known as "bevelled" or "mitre" wheels is used. Numerous illustrations of these may be found throughout the present work. Wheels of this kind are conical or frustræ of

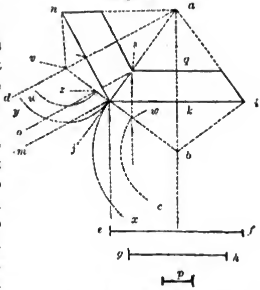
cones, with flutes on their surfaces, the corresponding projections and indentations of which working in contact produce motion. The form given to the teeth of wheels, as described in par. 399, is imparted to these flutes or projections; and the whole are placed on the surface of the cones so as to meet at the apeces, touching each other throughout their whole length. The section of the teeth is obviously not equal throughout, but diminishes towards the apex of the cone. To proportion the surfaces of the cones of two wheels working at right angles to each other is comparatively simple, the bevel or slope of each being determined thus: Suppose the shafts, or rather the central lines of the shafts, *a b*, *b c*, fig. 175, produced, they will meet in a point *b*, from which, if a line be drawn to the point where the circumferences of the two wheels meet, as at *d*, the slope or bevel *b d*, *b g*, or *b h*, will be found. But in some cases the shafts *a b*, *a d*, fig. 176, do not lie at right angles; to determine the form of the outline of the "cones" for bevel-wheels in such circumstances, proceed as follows: Let *a b*, *a d*, fig. 176, be the lines of the two shafts, *e f* the diameter of the pitch circle of wheel, *g h* that of the pinion. From a point *j*, parallel to *a b*, draw a line at a distance from *a b* equal to half of *e f*; draw the line *j m*, parallel to *a d*, at a distance equal to half of *g h*; join *j a*, and make *j i* equal to *e f*, and *j n* equal to *g h*, *j n* being at right angles to *a d*, and *j i* at right angles to *a b*; join *i a*, *n a*; set off from *k*, a distance *k q* equal to *p*, the breadth of the face or web of the wheel; parallel to *i j* draw *q s*, and parallel to *j n* draw *s t*; then *j s t n* is the form of the wheel, *j s q i* that of the pinion. To develop the surfaces on which to describe the teeth, proceed as follows: At right angles to *a j* draw from *j* a line, cutting the line *a b* in *b*; and also from *j* draw a line, cutting the line *a d* at *v*; join *v n*, *b i*. From centres *b* and *v*, with radii *b j* and *v j*, describe the arcs *j x*, *j y*; from *s* parallel to *a b* drop the line *s w*, cutting the line *b j* in *w*, and from *s*, a line *s o*, cutting the line *j v* in *z*. From centre *b*, with radius *b w*, describe the arc *w c*, and from *v* as a centre, with radius *v z* describe the arc *z u*. The larger and smaller circles thus formed are those on which the forms of the teeth are described, these all converging to the centres *v* and *b*.

Fig. 175.



BEVEL OR MITRE WHEELS.

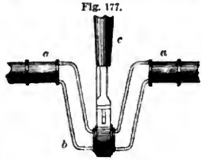
Fig. 176.



MODE OF SETTING OUT FORM OF MITRE-WHEELS.

406. A form of *wrought-iron crank* is illustrated at fig. 177: *a a* the journals of the two shafts, *b* the crank, *c* the connecting-rod; this is a "double crank." If only one-half of this was used, and the connecting-rod *c* gave motion to one shaft only, the crank would be a single one.

Fig. 177.



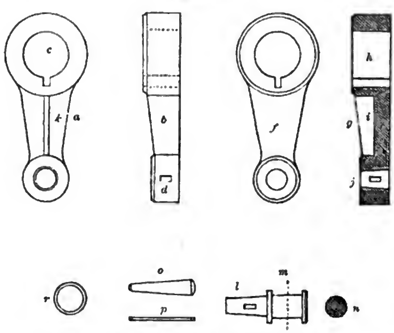
DOUBLE CRANK—SCALE, 1 INCH TO THE FOOT.

407. A usual form of *cast-iron crank* used for steam-engines is illustrated in fig. 178, where *a* is the front, *b* the side or "edge," and *f* the back view: a

section is shown at *g*. The end *a* of the crank-shaft, fig. 145, passes into the circular eyes *h*, *c*, fig. 178, and is keyed in by a key which passes into the key-seat or slot cut in the inside of the aperture *c*, *h*, as shown in the drawing. The eye *j* is that into which the "crank-pin" passes, and in which it is secured by the key or "cottar," which passes through a slot made at *d* in the end of the crank-eye, and also through a slot in the end *l* of the crank-pin. The part of the crank-pin embraced by the connecting-rod is shown at *m*, of which *n* is a section, and *r* an end view; *o* is the front and *p* the edge view of the cottar or key which secures *l* in the eye *j*.

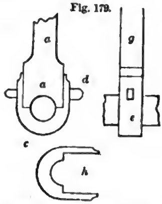
408. A simple form of connecting the end of a connecting-rod with the journal *m*, fig. 178, of a crank-pin, is shown at fig. 179, where *a a* is the termination of the connecting-rod; this being finished with a semicircle of same radius as the journal, as *m* in fig. 178. The strap or part *c* is similarly cut in

Fig. 178.



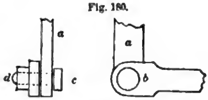
DIFFERENT VIEWS OF STEAM-ENGINE CRANK AND CRANK-PIN—SCALE, 1 INCH TO THE FOOT.

Fig. 179.



TERMINATION OR "BUTT" OF SIMPLE FORM OF CONNECTING-ROD—SCALE, 1 INCH TO THE FOOT.

Fig. 180.



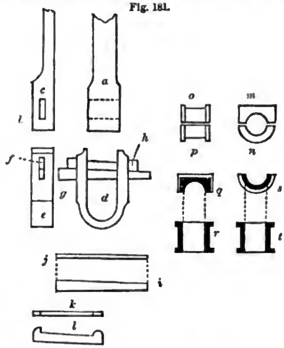
CONNECTING-ROD—SCALE, 1 INCH TO THE FOOT.

a semicircular form, and the end of the rod *a a* is passed between the forked ends *h*, and secured by a key or cottar. A side view of the connecting-rod and the strap is shown at *g*. In fitting the parts together, the journal of the crank-pin is embraced by the strap *h*; the end *a a* of rod is then passed between the ends of *h*, and the key *d* driven up. Another simple form of connecting the end of a connecting-rod with the crank-pin is shown at fig. 180, where *a a* represent the end of the crank, *b* that of the rod, which is provided with a circular aperture; the pin *c* is passed through this, and is secured to the crank by the bolt and nut *d*.

409. In both these forms the iron journal of the crank works in contact with the iron of the rod; to lessen the friction, brasses or bushes are provided, in which the journal revolves. A method of arranging the brasses is illustrated in fig. 181. The method of fitting the various parts together is as follows, *a* being a front and *b c* an edge view of the butt of the connecting-rod, *d* a front and *e f* an edge view of the "strap." The position of the "key" *g* and "gib" *h* is shown at *d*; *i* is an edge, *j* a side view of the key, *k l* corresponding views of the gib; *m n* front and *o p* edge views of the brasses; *q* a section, and *r* a sectional plan of the upper brass *m*, and *s t* corresponding views of

the lower brass *n*. In fitting together the parts, the lower brass *n* is put in its place in the semicircular termination of the strap *d*; the crank-pin journal is then embraced on its lower side by the brass and strap; the upper brass *o* is then made to embrace the upper side of the crank-pin journal; the butt *a* is then passed down the end resting on the brass *o*; the gib *h* is then placed in the slot *f*, and the cottar *g* driven up.

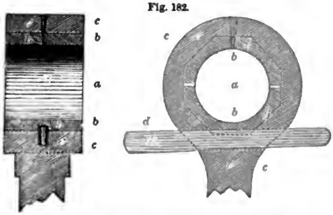
Fig. 181.



VARIOUS PARTS OF CONNECTING-ROD, "BUTT," "STRAP," AND "BUSHES"—SCALE, 1 INCH TO THE FOOT.

410. In fig. 182 the upper termination of a steam-engine connecting-rod is shown; *c c* the circular head of the rod, with the hexagonal eye *a*, into which the brasses *b b* are accurately fitted, and secured by the cottar *d*. A section is shown at the right hand of the cut; *a* is the part occupied by the crank-pin journal.

Fig. 182.



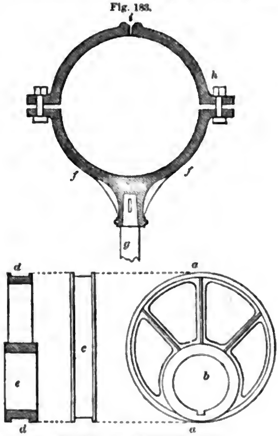
EYE OF CONNECTING-ROD—SCALE, 2 INCHES TO THE FOOT.

411. In some machines the continuous circular motion of a shaft is required to communicate a reciprocating rectilineal motion to another part, as to the pump-rod of an engine, or the shaker of a winnowing machine. A mode of effecting this is by employing a crank, the continuous revolution of which imparts a reciprocating movement to the connecting-rod. A usual method of effecting this movement in steam-engines is illustrated in fig. 183, which represents the various parts of an *eccentric*, as the contrivance is called. The body of the eccentric *a a* is of cast-iron, secured to the shaft which passes through the eye *b* by a key, as shown. The edge of the eccentric is not flat, but a rim or groove is turned, as shown at the edge view at *c* and section *d d e*. The ring *d d* is embraced by two straps *f f*, *h*, secured in two halves by bolts and nuts, as shown. The breadth of these is such as to admit of easy play between the projecting parts *d d*; and to insure ease of working, segmental pieces of brass are riveted by copper rivets to the inside of the straps *f f*, *h*, the brasses working in contact with the periphery of the eccentric ring *d d*; the oil for lubrication is passed through the oil-hole *i*. The connection of the rod is shown at *g*. The "throw" of the eccentric, or extent of the up-and-down motion of the rod, is just twice that of the distance of the real centre of the eccentric ring from that on which it is fixed to the shaft. Thus in fig. 183 the extent of movement of the rod *g*, or the "lift" of the pump-rod to which we may suppose it is attached, is just twice the distance of the centre of the eye *b* from the centre of ring *a a*.

412. Reciprocating movement is sometimes obtained from continuous circular by means of "cams." A common form of *cam* is that known as the "heart-

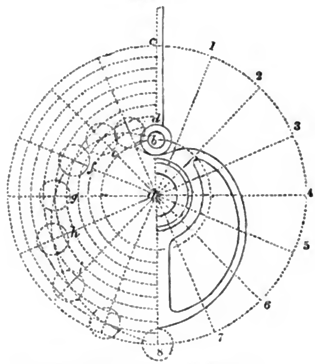
wheel" illustrated in fig. 184. In the eccentric in fig. 183, the reciprocating movement of the rod *g* is not uniform throughout its stroke, the velocity in-

Fig. 183.



ECCENTRIC, AND ECCENTRIC STRAP—SCALE, 1 INCH TO THE FOOT.

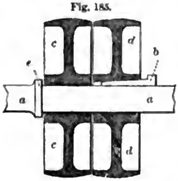
Fig. 184.



MODE OF SETTING A CAM FOR UNIFORM MOTION.

creasing during its first half, and decreasing during its second half. Uniform motion is obtained by the heart-shaped wheel, when its outline is produced as follows: Let *b c*, fig. 184, represent the vertical distance through which the rod, as *c d*, has to rise and fall, and *a* the centre of the cam. From *a*, as centre, with *a b*, *a c*, describe the circles through *b* and *c*. Divide the circle *a c* into any number of equal parts, as 16, 1, 2, 3, &c., and draw as many radial lines from *a*; divide the distance *c b* into half as many, or 8; and from *a*, as centre, describe circles passing through these 8 points in *b c*. These circles will intersect the radial lines drawn from *a*; if then a curve be drawn by hand through the points of intersection, it will form the outline of a cam, which by its revolution will enable the point *b* to rise to *c* during a half revolution of the shaft, while it will allow it to fall from *c* to *b* during the other half revolution—the motion being uniform both in the rise and the fall of the rod *d c*. In practice a roller is fixed at the end of the rod, the centre of which is the point *b*. Let *b d* be the radius of the roller or friction-wheel; at the various points of intersection, describe circles corresponding to *b d*, and through the points, as *e f g h i*, draw a curve; this will form the true outline of the cam, in contact with which the roller *b d* revolves.

Fig. 185.



FAST-AND-LOOSE PULLEY—SCALE, 1 INCH TO THE FOOT

413. The plan most usually adopted by which machinery is disengaged and engaged, or put "out of" or "in gear," as it is technically termed, is the "*fast-and-loose pulleys*," illustrated in fig. 185, where *a a* is the shaft, *e* the journal, *c c* a pulley revolving loosely on the shaft, *d d* a similar pulley keyed on the shaft by the key *b*. While the driving-belt is kept running on the pulley *c c*, no motion is imparted to the shaft, as the pulley revolves loosely

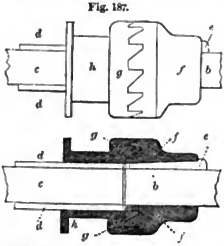
on it; but on being shifted from the loose pulley *c c* to the fast one *d d*, motion is imparted to the shaft *a a*. As the belt is gradually passed from *c c* to *d d*, or the contrary, the shaft is set in motion or at rest gradually, and comparatively little shock is experienced.

414. Another method of engaging and disengaging machinery is by the *sliding-clutch*, fig. 186, where *a a* are the two shafts, *b b* the journals, each provided with "clutches" or "glands" *c d*, having corresponding projections and indentations which interlock with each other; so that if *c* is at rest and *d* in motion, and *d* is gradually brought in contact with *c*, motion is communicated to *c*. The clutch *d* is not fixed on the shaft, but has a lateral movement along two ribs *e e*, which pass into corresponding slots made in the eye of the clutch *d*. These ribs or feathers serve at the same time to carry round the clutch with the revolution of the shaft. In fig. 187 we give an elevation and section of another form of sliding-clutch. The same letters refer to both views,

Fig. 186.

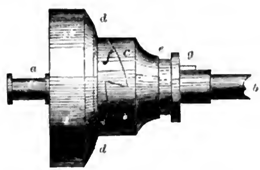
SLIDING CLUTCH FOR ENGAGING AND DISENGAGING SHAFTS— SCALE, ¾ INCH TO THE FOOT.

Fig. 187.



CLUTCH FOR ENGAGING AND DISENGAGING SHAFTS— SCALE, 1 INCH TO THE FOOT.

Fig. 188.

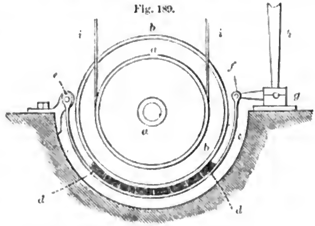


CLUTCH OR GLAND FOR ENGAGING AND DISENGAGING SHAFTS— SCALE, ¾ INCH TO THE FOOT.

of which the upper is the elevation and the lower the section, *c b* the two shafts, *f f* the fixed clutch keyed on by the key *e*. *g g h* the sliding clutch, *d d* the ribs or feathers. In fig. 188 another form of sliding-clutch is shown, where *a* is the journal of a shaft in which the wheel *d d* is keyed: curved projections, as *f*, are cast to the wheel, which take into correspondingly curved recesses *c* made in the clutch *e*, which slides on the rib or feather *g* on the other shaft *b*.

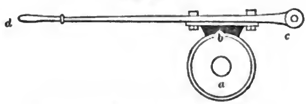
415. The rate at which wheels—such as those of hoisting-cranes—revolve, is regulated by means of a *friction-brake*. Let *a a*, fig. 189, be a pulley, with the driving-belt or chain *i i* passing round it; let *b b* be the friction-pulley fixed on the same shaft as carries *a*. Part of the periphery of the pulley *b b* is embraced by a series of wood-blocks *d d*, carried by the iron strap *c c*, jointed at one end to the stud *e*, and at the other to the lever *f* of the belt-crank *h f*, the centre of which is on the pedestal *g*. By

Fig. 189.



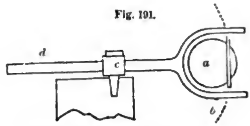
FRICTION-BRAKE—SCALE, ¾ INCH TO THE FOOT pulling down the end of *h*, the blocks of wood are tightened up against the periphery of the pulley *b b*, the friction created moderating its velocity. In fig. 190 we give a simpler form: *a* is the pulley, with a block of wood *b* in contact with its periphery; this is attached to a lever *c d*, jointed at *c*; by pressing on the end *d* of the lever the block *b* is brought into contact with the periphery of the pulley *a*.

Fig. 190.



FRICTION-BRAKE—SCALE, ½ INCH TO THE FOOT.

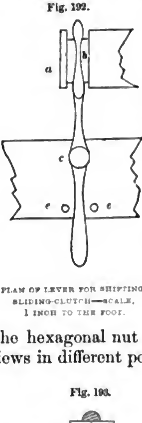
Fig. 191.



LEVER FOR SHIFTING SLIDING-CLUTCH—SCALE, 1 INCH TO THE FOOT.

416. In the fast-and-loose pulley described in par. 413, the belt is usually shifted from one pulley to the other by hand. In putting the sliding-clutch, as illustrated in figs. 186, 187, and 188, into and out of gear, a lever is used, as illustrated in fig. 191, where *a* represents the section of the journal of the clutch, as *h* in fig. 187: this is embraced by the forked extremity *b* of the lever *d*, which vibrates on the pin *c* fixed to part of the machine; by moving the extremity of the lever *d* from right to left, the sliding-clutch is moved into or out of contact with the fixed clutch. In fig. 192 a plan of the *clutch-lever* is shown; *a* the journal of the clutch, *b* the end of lever, *c* the pin on which it vibrates, *e e* pins which retain the lever in any position desired, either keeping the clutches in contact or separate. When the lever is between these two pins *e e*, the clutches are out of gear.

Fig. 192.

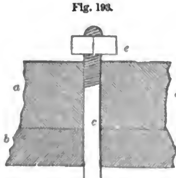


PLAN OF LEVER FOR SHIFTING SLIDING-CLUTCH—SCALE, 1 INCH TO THE FOOT.

417. We shall now illustrate a few of the methods employed to fit together the essential parts of machines. Two pieces of iron, as *a a*, *b b*, fig. 193, or of wood, are united together by means of bolts and nuts; *c* is the bolt, *d* the "head" of the bolt, *e* the nut.

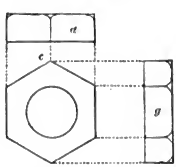
418. *Nuts* are usually made square and hexagonal. The hexagonal nut is illustrated in fig. 194, where *a* is the plan, *g* and *d* edge views in different positions.

Fig. 193.



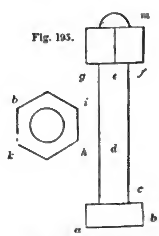
BOLT AND NUT—SCALE, 1 INCH TO THE FOOT.

Fig. 194.



HEXAGONAL NUT—SCALE, 2 INCHES TO THE FOOT.

Fig. 195.



PROPORTIONS OF BOLTS AND NUTS—SCALE, FIG. 190.

419. In fig. 195 we give an illustration showing the proportions observed between the different parts of hexagonal nuts and bolts. Where the diameter of bolt *d*

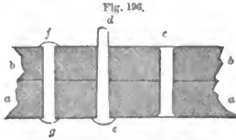
is $\frac{1}{2}$ an inch, thickness of head $b\ c = \frac{7}{16}$, thickness of the "nut" $f\ m = \frac{9}{16}$, breadth of nut over the sides, as $h\ i$, 1 inch, and breadth over angles, as $h\ k$, $1\frac{1}{8}$ inch.

Diameter $\frac{3}{4}$ inch, $b\ c = \frac{5}{8}$, $f\ m = \frac{7}{8}$, $h\ i = 1\frac{3}{8}$, $h\ k = 1\frac{1}{2}$ inch.
" 1 " $b\ c = \frac{3}{4}$, $f\ m = 1\frac{1}{8}$, $h\ i = 1\frac{3}{4}$, $h\ k = 2$ "
" $1\frac{1}{4}$ " $b\ c = \frac{7}{8}$, $f\ m = 1\frac{7}{16}$, $h\ i = 2\frac{1}{8}$, $h\ k = 2\frac{7}{16}$ "
" $1\frac{1}{2}$ " $b\ c = 1\frac{1}{8}$, $f\ m = 1\frac{11}{16}$, $h\ i = 2\frac{1}{2}$, $h\ k = 2\frac{7}{8}$ "
" 2 " $b\ c = 1\frac{5}{8}$, $f\ m = 2\frac{1}{4}$, $h\ i = 3\frac{1}{4}$, $h\ k = 3\frac{1}{2}$ "

For other and intermediate sizes, see p. 208 of Weale's *Engineer's Pocket-Book for* 1855-6.

420. Plates of wrought-iron are frequently connected together by means of *rivets*. Fig. 196 illustrates the usual method of making the joints. Where *a a b b* are the two plates to be joined, holes at certain distances are bored or punched through both the plates, and countersunk, as at *c*, by enlarging the hole for some distance in the thickness of the plate, or the ends of the holes may be left plain. The rivets formed with a head *e* at one end are inserted red hot in the holes, and the upper end *d* hammered, as at *f*, a resistance being made at the part *g* while the head *f* is being hammered. The two plates are thus closely bound together.

Fig. 196.



MODE OF RIVETING PIECES OF IRON—SCALE, FIG 130.

421. Mr Fairbairn, to whom the engineering world is so much indebted for valuable investigations, has also thoroughly examined this department of mechanical construction. The experiments instituted had special reference to two forms of riveting, one in which a single row of two rivets was placed across the plate thus ° °, this being termed the "single-riveted joint," the other form having three rivets placed thus ₒ ° ₒ, this being termed the "double-riveted joint." The result of the experiments proved that the loss of strength by the use of the single-riveted joint, "including loss caused by the rivet-holes, is not less, under ordinary circumstances, than 40 per cent. During the whole of the experiments on single-riveted joints, it was observed that the ends of the plates under strain curled upwards on each side, and produced a diagonal strain upon the joint. . . . This position gave an oblique direction to the forces, and caused the plate to break in some degree transversely through the rivet-holes. In order to obviate this defect, and prevent as much as possible a transverse strain upon the plates through the points in contact, the lap was increased, and a third rivet introduced to keep down the ends of the plates." This is shown in the form of double-riveted joints as above. This form of joint "gives a considerable accession of strength, and exhibits several important facts in connection with the construction of vessels exposed to severe pressure," and "the plates appear to retain their position under strain much better than single-riveted joints."

422. Taking the mean breaking-weights of "single" and "double" riveted joints, and comparing them with the section of a "plate itself, the areas being the same, we have for the tensile strength of the plates—

	Section of iron torn asunder.		lb.
Solid plate, ...	.44	=	25,400
Double-riveted joints, ...	.44	=	25,707
Single do. do.	.44	=	18,590

Assuming, therefore, the strength of the plates to be 1000, we have—

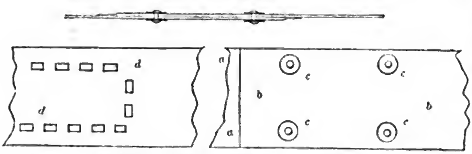
For the strength of plates of equal sections, ...	1000
For double-riveted joints, ...	933
For single do. do.	731

We may safely assume these ratios as the comparative values of jointed plates of equal sections, when acted upon by a force calculated to tear them asunder. The correct value of the plates, computed from a sectional area taken through the rivet-holes, will therefore be to their riveted joints as 100, 93, and 73, or, in round numbers, as 10, 9, and 7. In addition to a loss of nearly one-tenth in the double-riveted joints, and three-tenths in the single ones, it will be observed that the strength of the plates is still further reduced by the quantity of iron punched out for the rivets. For this loss of metal 30 per cent will have to be deducted from the above ratios, thus giving the absolute strength of the plates to that of the riveted joints as 100, 68, and 46. "In some cases, where the rivets are wider apart, the loss sustained is, however, not so great; but in boilers and similar vessels, where the rivets require to be close to each other, the edges of the plates are weakened to that extent. In this estimate we must, however, take into consideration the circumstances under which the results were obtained, as only two or three rivets come within the reach of experiment; and again, looking at the increase of strength which might be gained by having a greater number of rivets in combination, and the adhesion of the two surfaces in contact, which in the compressed rivets by machine is considerable, we may fairly assume the following relative strengths as the value of plates with their riveted joints. Taking the strength of plate at 100, the strength of the double-riveted joint would then be 70, and the strength of the single-riveted joint 56. These proportions may therefore in practice be safely taken as nearly the standard value of joints such as are used in vessels where they are required to be steam or water tight, and subjected to pressure varying from 10 lb. to 100 lb. upon the square inch." We shall in a succeeding paragraph give a table showing the strongest form and best proportions of rivets for joints, deduced from Mr Fairbairn's valuable experiments.

423. Where flush joints or even surfaces are required in riveting, the holes are "countersunk," as it is termed, the ends of the rivets being hammered into the cavities, giving them a conical form. This will of necessity lessen the strength of the riveted joints. "It is, however, satisfactory to know that countersinking the heads of the rivets does not seriously injure the joint in its powers of resistance to a direct tensile force; but the rivets are liable to start when exposed to collisions or a strong impinging force, such as the sides of ships are frequently doomed to encounter."

424. Driving-belts may be joined together by leathern thongs, as shown at *d*, fig. 197. A better method is to rivet the two, *a a*, *b b*, together by small copper rivets, as *c c*, tin washers being used, as at *c c c c*.

Fig. 197.

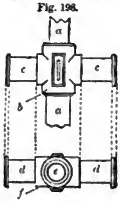


JOINING OF LEATHER DRIVING-BELTS—SCALE, IN FIG. 130

425. Wheels, pulleys, &c. are keyed on to the shafts, as represented in fig. 170, in which the "key-seat" is cut in the eye of the wheel, and the periphery of the shaft is slightly flattened at the place where the key is driven up. To the piston-rod *a a*, fig. 198, the cross-head *b* is secured by a key or wedge driven through the box *b* and piston-rod. The brasses of the connecting-rod embrace the parts *c c*, *d d*; the piston-rod passes through the hole *e*. The lower figure *d d* is a plan of the upper *c c*.

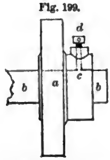
426. For small wheels as *a*, fig. 199, a *pinching-screw* as *d* may be used to connect them to the shaft *b b*. The screw passes through the boss *c*, and tightens on the shaft *b b*.

Fig. 198.



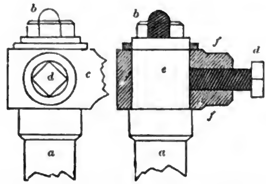
ELEVATION AND PLAN OF PISTON-ROD "CROSS-HEAD"—SCALE, 1 INCH TO THE FOOT.

Fig. 199.



FIXING OF PULLEYS, &c. ON SHAFTS BY PINCHING-SCREWS—SCALE, 1 INCH TO THE FOOT.

Fig. 200.

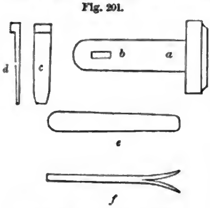


ELEVATION AND SECTION OF VERTICAL SPINDLE AND HANDLE—SCALE, 1½ INCHES TO THE FOOT.

427. This method is also illustrated in fig. 200, where part of a handle *c* is fixed to the upper termination *e* of the shaft *a*, *a*, which it is employed to turn. The screw *d* passes through the boss *f f*. The two are further secured together by bolt and nut, as at *b b*.

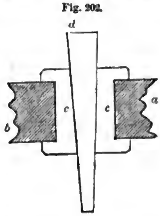
428. When a *bolt* is used for a movable joint, as at *c*, fig. 204, it is made as in fig. 201; a slot is made at *b*, through which the key *c* is driven; *d* is an edge

Fig. 201.



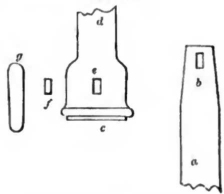
PINS AND KEYS—SCALE, 3 INCHES TO THE FOOT.

Fig. 202.



GIBS AND COTTAR, OR KEY.

Fig. 203.



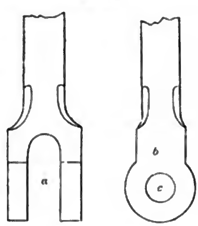
JUNCTION OF RODS OR LEVERS—SCALE, 1½ INCHES TO THE FOOT.

view of the key; the bolt *a* is previously passed through the eyes of the rods to be jointed; *e* is a side and *f* an edge view of a "split key."

429. In fig. 202 we give what are termed *gibs* and *cottars*, or *keys*. The parts *a b* are forced asunder or tightened up against the parts upon which they rest or butt, by driving up the key or cottar *d* between the gibs *c c*.

430. In fig. 203 we illustrate a method sometimes adopted of effecting a junction between one rod *a b* and another *c d*. The end of *c d* is hollow, to admit the extremity *b* of *b a*. Slots are cut in both sides of *c d* at *e*, exactly opposite each other; a corresponding key-slot is cut in *a b* at *b*. When the end of *a b* is inserted in *c d*, a key *g* is driven through the three holes: *f* is an end view of the key *g*. The end of a lever is sometimes jointed, as in fig. 204, *a* being the edge view, *b* the front. The bolt, as *a b*, fig. 201, passes through *c*.

Fig. 204.

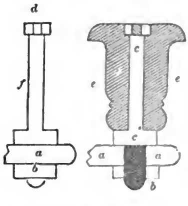


JOINED END OF LEVER—SCALE, 1½ INCHES TO THE FOOT.

431. In fig. 205 we illustrate a method of attaching the movable handle

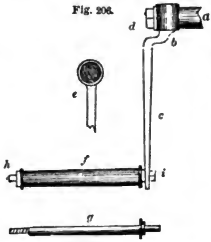
which terminates the lever c, fig. 200, for turning the shaft a, a. The part e e, fig. 205, is usually made of wood, in the central aperture of which c c, the stud f revolves loosely, which is screwed to the end of the lever a a by the nut b. The illustration to the right of the cut is in section. In fig. 206 we give another method of forming a handle. Let a be the shaft, to turn as the shaft of a churn, &c.; b c the handle secured to the end of the shaft a by a nut d; the end a is reduced so as to form a shoulder which passes through the eye e of the handle, as shown at section e. The loose part f is secured to g by the nut h, while g is secured to the lower termination of the handle c by the nut i.

Fig. 205.



FIXING OF WOOD HANDLE OF IRON LEVER —SCALE, 1 INCH TO THE FOOT.

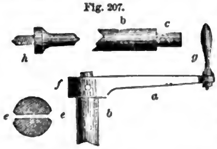
Fig. 206.



FIXING OF WOOD HANDLE TO IRON RODS—SCALE, ¾ INCH TO THE FOOT.

432. A lever b, b, fig. 207, as the stud of a "throttle-valve" of a steam-engine, &c., may be worked by the handle a riveted to the shoulder c, made in the end of the shaft b, by a rivet passing through a hole made in the eye of the handle a, as shown at e e, which is a section of the eye of f. The handle g is secured to a by bolt and nut; the lower part is formed as at h, which gives a shoulder and part to form the bolt as shown. The above may be used to turn a screwed lever, as g, fig. 166. Where the lever-wheel is used, as at e, fig. 165, the parts are connected as in fig. 208; c the shaft corresponding to a, fig. 165, a a the wheel, keyed or riveted on as at e; the handle b is riveted on to an eye d, shown in the plan of wheel.

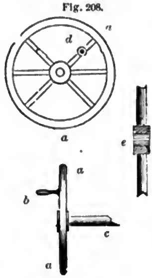
Fig. 207.



FIXING OF IRON HANDLES OR LEVERS TO RODS —SCALE, 1 INCH TO THE FOOT.

433. Before giving the "rules" to calculate the dimensions of the various parts of mechanism we have attempted to describe, we shall here give a few remarks on the subject of *fly-wheels* — a matter of some importance in the construction of many machines of the farm, as chaff-cutters, pointing out where these auxiliaries to machinery may with propriety be applied, and where they ought not.

Fig. 208.



FIXING OF LEVER OR HAND-WHEEL TO RODS—SCALE, ¾ INCH TO THE FOOT.

434. In the first place, it may be asserted that in no case can a fly-wheel act as a *generator* of power; and under a false impression of this supposed function of fly-wheels, numerous instances occur of their misapplication, or at least a misconception of their effects; and, secondly, the only available function of fly-wheels is their capability of acting as *reservoirs* of that power or force that is communicated to them while in motion. Thus a comparatively small force applied to a heavy fly-wheel for a few seconds, will, on the principle of its absorbing and partially retaining that power and force, accumulate a momentum that may, through the agency of mechanical means, be discharged on

a particular point, and produce an instantaneous effect that the first mover never could accomplish without such means. This is finely exemplified in the machine for punching and cutting thick iron plates and bars; and the principle applies in all cases where fly-wheels can be employed with advantage. The principle of action is this: Fly-wheels may be employed with advantage in every case where the intensity of either the *power* or the *resistance* is variable; and where both are variable, it becomes still more necessary. On the other hand, where both the power and the resistance are uniform, a fly-wheel may be held as an encumbrance, and can only act as a load upon the first mover. In the steam-engine, for example, of any form in which a crank is used to communicate motion to machinery, the fly-wheel is indispensably necessary; and such is the requisite governing power of a fly-wheel to keep up steady motion, that its momentum is sufficient to compensate for considerable variation in the resistance of the machine or machinery upon which it operates. With water-wheels, however, the power is perfectly uniform, and if the resistance is also uniform, as in grist-mills and even thrashing-mills, fly-wheels will be worse than useless; but where the resistance is intermitting, such as rolling and tilt mills, and punching machines, a heavy fly-wheel becomes necessary, in which the power of the first mover can be accumulated for a short period, and which will be expended during the succeeding short period that the driven machine is in action. In every case where manual power is applied, fly-wheels are useful if not essential. This arises from the power itself being variable; for the power of a man working a winch varies according to the different positions which the winch occupies in the course of its revolution, and has been ascertained to range in the proportion of 30 lb. and 60 lb. The rationale of this is, that when he is in a position that restricts his exertion to 30 lb., he might not be able to overcome the resistance unless at a very slow rate; but in the position where he can exert a force of 60 lb., he can do more than overcome the resistance. And here it is that the fly-wheel comes to his aid; for suppose the resistance requires an actual force of 45 lb., while he is putting forth 60 lb., there is a surplus of 15 lb. The ever-ready fly-wheel, whose velocity, from its inertia, he is not able greatly to increase, takes up, with a small increase of velocity, this surplus force exerted by the hand; and this is stored up in the mass of the wheel, to be delivered out again at the next weak point in the revolution of the winch. Hence a nearly equable force is produced to act upon the machine to which the power of the man is directed. If this power is directed upon an intermitting machine, such as a straw-cutter, the demands upon the fly-wheel are very much increased; but as the point of the machine to which the power is applied moves at a much slower velocity than the centre of gyration in the fly-wheel, and as the intermissions of the resistance are not likely to coincide exactly with the increments or decrements of the power, there will be a mutual compensation going on amongst the forces to bring out a uniform result. There is a possibility that a coincidence of the above circumstances may occur; hence, it is sometimes of consequence to observe the placing of the winch so as to counteract any defect of compensation.

435. The power of horses to impel machinery being of nearly uniform intensity, requires no regulator in itself; but it comes under the general law, if the resistance is intermitting. Thus, in the thrashing-machine, which is slightly variable in resistance, it would, if worked with horse-power, be considerably improved by the addition of a well-proportioned fly-wheel. In various other machines worked with horse-power, where the resistance is frequently intermitting, such as blowing bellows, pumping, and the like, a fly-wheel is indis-

pensable; while in a malt or other mill, whose resistance is uniform, the fly-wheel would be an encumbrance. Steam-power applied to a thrashing-machine requires, as already observed, no additional fly-wheel, but that the steam-engine for such purpose should be above the standard allowed for ordinary purposes.

436. The general *theory* of the application of fly-wheels may be repeated in a few words. They are usefully employed in all cases of intermitting resistance and of variable force, whether in the first mover or in the resistance. Where the motion is uniform and not intermitting, the first mover being also uniform, the fly-wheel is in almost every case unnecessary, and frequently an obstruction.

437. The *strains* to which *lying-shafts* are subjected, are, first, "lateral," their weight and that of the wheels, &c. which they support, tending to break or to deflect them; second, "torsion," or twisting—the strain causing this arising from the resistance of the work to be performed. A shaft is exposed to rupture by torsion, when the force at one end is greater than at the other, or when the forces at the end act in opposite directions.

438. The lateral strain, and tendency to rupture by torsion of all shafts, should be estimated; and where one exceeds the other, the greatest strain should be calculated for. The following rules are extracted from Mr Cresy's work, *Cyclopædia of Civil Engineering*, Longman and Co.: "For the *lateral stress* in cast-iron shafts, the weight w in pounds, acting in the length l in feet, the formula is,

$$\sqrt[3]{\frac{w \times l}{500}} = \text{diameter.}$$

For malleable iron the result must be multiplied by 0.935; for oak, 1.83; for fir, 1.72; and for shafts to resist *torsion*, we have in horse-power h, that the shafts will drive, making turns n per minute,

$$\sqrt[3]{\frac{240 \times h}{n}} = \text{diameter for cast-iron.}$$

For malleable iron the result must be multiplied by 0.963; for oak, by 2.238; and for fir, 2.06: these are for shafts of first movers; for second movers, multiply the result by 0.8; and for third, by 0.793."

439. Hollow shafts of cast-iron are less liable to rupture by torsion than solid; a good proportion for the thickness of the metal is two-tenths of the entire diameter. The following table, showing the diameter of hollow cast-iron shafts to resist "lateral" strain, is compiled from one given by Mr Cresy in the work above referred to. The letters E. D. denote exterior diameter in inches, I. D. interior diameter; S=4 S=6, &c., denote the stress or strain to be 4 or 6 times, &c. the weight of the shaft.

Length.	E. D.	I. D.	E. D.	I. D.	E. D.	I. D.	E. D.	I. D.
4	1.5	0.9	1.9	1.1	2.2	1.3	2.4	1.4
6	2.8	1.6	3.5	2.1	4.0	2.4	4.5	2.7
8	4.3	2.5	5.3	3.1	6.1	3.6	6.9	4.1
10	6.0	3.6	7.4	4.4	8.5	5.0	9.5	5.7
12	7.9	4.7	9.8	5.8	11.2	6.7	12.6	7.5
	S=4		S=6		S=8		S=10	

"When the diameter of a shaft is found for cast-iron, by multiplying this diameter by .935 the product will give a diameter for a shaft of equal stiffness, made of wrought-iron; and a shaft of fir should be 1.716 times the diameter of a cast-iron one, and of oak 1.83 times, in order to be of equal stiffness."

Diameter of Shafts in inches.	Revolutions of Shafts per Minute.			
	10 Horse Power.	20 Horse Power.	30 Horse Power.	40 Horse Power.
2	0.33	0.66	0.99	1.33
3	0.13	2.25	3.37	4.5
4	2.66	5.33	7.99	10.36
5	5.2	10.4	15.6	20.8
6	9.0	18.00	27.0	36.0

440. The preceding table is also compiled from Mr Cresy's work; it shows the diameter of cast-iron shafts to resist torsion. "When the cylindrical shafts are hollow, the diameter must be multiplied by 1.05; and when the shafts are laid horizontally, something should be added to what is given in the foregoing tables, as they are calculated for vertical shafts. When the shaft is of wrought-iron, multiply the diameter found by 0.963; if of oak, by 2.238; when of fir, by 2.06." The reader will find complete tables of the dimensions of cast-iron and wrought-iron shafts in Adcock's *Engineer's Pocket-Book for* 1857.

441. The journals of shafts should be at the least equal in length to the diameter, if the load is heavy; one and a half to two times may be the proportion used. A journal twice as long as the diameter will be easily lubricated.

442. The following rules will be useful to proportion the diameters of wheels and pulleys, so that they will work satisfactorily. First, as to *pulleys:* Suppose we have two pulleys to run at so many revolutions each, let n represent the number of revolutions of one of the pulleys; let the diameter of one of them be known, and let this be represented by d; to find the diameter of the other, the velocity of which is given, and which will be represented by o, then

$$\frac{n \times d}{o} = \text{the diameter.}$$

Example: Let a pulley 24 inches in diameter have a velocity of 80 revolutions per minute—to find the diameter of another pulley, the velocity of which is 50—then

$$\frac{24 \times 80}{50} = 38.4 \text{ inches in diameter.}$$

443. As before stated, in par. 398, in designing *toothed wheels*, the diameters of the pitch-circles must be proportional to the number of teeth in the wheels. To proportion these, the following data must be known: 1. The radii of the pitch-circles of the two wheels, and the number of the teeth of one of them; 2. The number of the teeth in each of the wheels, and the radius of one of them; 3. The distance between the centres of the two wheels, and the number of teeth of both of them. The following formulæ are given for these three cases:—

444. Case 1: Let l be the radius of the large wheel, s that of the small one, and n the number of teeth of the large wheel; then

$$\frac{n \times s}{l} = \text{number of teeth in the small wheel.}$$

Case 2: Let l represent the number of teeth in the largest wheel, s in that of the smaller one, and r the radius of a larger wheel; then

$$\frac{s \times r}{l} = \text{radius of the pitch-circle of the smaller wheel.}$$

Case 3: Let d be the distance between the centres of the two wheels, l the number of teeth of the larger wheel, s the number of teeth of the smaller one; then

$$\frac{d \times l}{s + l} = \text{radius of pitch-circle of the largest wheel.}$$

This, being subtracted from the distance between the centres, will obviously give the radius of the other or smaller wheel.

Case 4: To these cases may be added another—namely, where the distance between the two wheels is known, and the number of revolutions of each. Thus: Let d represent the distance between the wheels, l the number of revolutions of the fastest-going wheel, s that of the slowest—then

$$\frac{d \times l}{l + s} = \text{radius of large wheel.}$$

The radius of the smallest being found by subtracting the radius of the largest from the distance between the centres of the wheels.

445. For the following table of the proportions of the parts of toothed wheels we are indebted to Templeton's *Workshop Companion*:—

Length of the teeth, ...	= $\frac{5}{7}$ of the pitch.
Thickness, ...	= $\frac{3}{7}$ of the pitch.
Breadth of face, ...	= $2\frac{1}{2}$ times the pitch.
Edge of the rim, Projecting rib inside the rim, Thickness of flat arms, .	= each $\frac{4}{7}$ of the pitch.
Breadth of arms at rim, . .	= 2 teeth and $\frac{1}{4}$ pitch, increasing in breadth towards the centre of the wheel in the proportion of $\frac{1}{2}$ an inch for every foot in length.
Thickness of the ribs or feathers in the arms,	= $\frac{1}{4}$ of the pitch.
Thickness of metal around the eye or centre,	= $\frac{5}{8}$ of the pitch.

446. For tables of the dimensions of the teeth of wheels to transmit certain power, &c., the reader is referred to Weale's *Engineer's Pocket-Book for* 1855-1856. The following notes on this important subject by Mr Buchanan will be useful: "Multiply $\frac{1}{4}$ of the square of the pitch in inches by the breadth of the teeth in inches—the product is the horse-power that the teeth will transmit when the pitch-line passes through 4 feet per second. In quick speeds or fractional pitches it may be more convenient to take the following rule: Multiply the square root of the pitch in inches by the breadth of the teeth in inches—the product is the horse-power at 10 feet per second. A general rule to ascertain the length of the teeth is, to take $\frac{1}{3}$ of the pitch for the distance from the root to the pitch-line, and $\frac{1}{4}$ of the pitch for the distance from the pitch-line to the top. When wheels drive pinions, let no pinion have less than 8 teeth, rather 10 or 12 if convenient: when pinions drive wheels, let no pinion have less than 6 teeth, rather 8 or 9. The number of teeth in a wheel should be prime to the number of teeth in its pinion. To increase or diminish velocity in a given proportion, and with the least quantity of wheel-work: let the number of teeth

on each pinion be to the number of teeth on its wheel as 1 : 3.59. Even to save space and expense, never let the ratio exceed 1 : 6." *

447. In designing and arranging mechanism, it is sometimes necessary to know, first, the velocity of the circumference of a wheel, pulley, or fly-wheel, when the number of its revolutions per minute are known; or, second, the number of revolutions it makes per minute when the velocity of its circumference is known. For these two cases the following rules may be useful:

Case 1: Let d be the diameter of the wheel, and n the number of revolutions it makes per minute: then multiply the diameter by 3.1416, which gives the circumference c of the wheel; multiply the circumference by the number of revolutions, and the product will be the space passed through per minute by any point in the circumference, which, divided by 60, will give the velocity of the circumference in feet per second.

Case 2: Let v be the velocity of the wheel in feet per second, and c the circumference of the wheel: then multiply the velocity by the circumference; the product obtained is then to be multiplied by 60, which gives the number of revolutions per minute.

448. The circumferential velocity of the rim of a fly-wheel, or any point near its centre, as the pitch-line of a toothed wheel, may be ascertained by marking any point on the rim of the wheel, and observing how frequently this point passes any fixed point during any number of seconds; then multiply the number of revolutions recorded by the circumference of the wheel or rim, and divide by the number of seconds of observation—the quotient will be the circumferential velocity.

449. The determination of the weight of a fly-wheel for any given purpose, is a problem not very definite in its results; but approximations to it have been made by men of eminence. Amongst these, we find Tredgold stating a rule for the fly-wheels of steam-engines,† which, for practical purposes, is convenient, and comes near to the general practice, though this is to be taken with considerable latitude, seeing that the practice of engineers differs considerably on this point; and the rule, though it applies to heavy fly-wheels with tolerable exactness, does not agree with practice in the case of fly-wheels for the hand, and other small machines. But the following approximation will be a tolerable guide in practice for the weight of small fly-wheels.

450. Taking the average force that a man will exert in turning a winch of 12 inches radius at 23 lb., when he turns it 45 times per minute, the rule will be—

Rule.—Multiply 20 times the force in pounds exerted on the winch by its radius in feet, and divide this product by the cube of the radius of the fly-wheel in feet, multiplied into the number of the revolutions per minute; the result will be the area of a section of the rim of the fly-wheel in square inches.

Example.—The force applied to the winch being 23 lb., its radius 1 foot, and the revolutions per minute 45, required the section of the rim of a fly-wheel whose radius is $1\frac{1}{2}$ foot, or 3 feet diameter.

$$\frac{20 \times 23 \times 1}{1.5^3 \times 45} = \frac{460}{151.8} = 3 \text{ inches, the area of section of the rim.}$$

451. Though this formula will serve for small fly-wheels, whose velocities range from 40 to 80 revolutions per minute, it becomes necessary, in order to make it agree with practice, to change the constant multiplier. Thus, for velocities ranging from 80 to 150, the number 10 will be substituted for 20; and

* Buchanan *On Mill-work and Machinery*, p. 116.

† Tredgold *On the Steam-Engine*, p. 266.

from 150 to 300, the number 5. In this last case the fly-wheel cannot exceed 2 feet diameter, and in the former it is restricted to 3 feet.

452. The following table is given by Mr Fairbairn "for proportioning the distances and strength of rivets in joints requiring to be steam or water tight:—

Thickness of Plates in inches.	Diameter of Rivets in inches.		Length of Rivets from the head in inches.		Distance of Rivets from centre to centre in inches.		Quantity of Lap in single joints in inches.		Quantity of Lap in double joint in inches.
.19 = $\frac{3}{16}$	.38		.88		1.25		1.25		For the double-riveted joint add two-thirds of the depth of the single lap.
.25 $\frac{4}{16}$	.50		1.13		1.50	6	1.50	6	
.31 $\frac{5}{16}$	.63	2	1.38		1.63		1.88		
.38 $\frac{6}{16}$	.75		1.63	4.5	1.75	5	2.00	5.5	
.50 $\frac{8}{16}$	.81		2.25		2.00		2.25		
.63 $\frac{10}{16}$	.94	1.5	2.75		2.50	4	2.75	4.5	
.75 $\frac{12}{16}$	1.13		3.25		3.00		3.25		

453. "The figures 2, 1.5, 4.5, 6, 5, 4, 6, 5.5, 4.5, in the preceding table, are multipliers for the diameter, length, and distance of rivets; also for the quantity of lap allowed for the single and double joints. These multipliers may be considered as proportionals of the thicknesses of the plates to the diameter, length, and distance of rivets. For example, suppose we take $\frac{3}{8}$ plates, and required the proportionate parts of the strongest form of joints, it will be—

$.375 \times 2 = .750$, diameter of rivet, $\frac{3}{4}$ of an inch.
$.375 \times 4\frac{1}{2} = 1.687$, length of rivet, $1\frac{3}{4}$ inches.
$.375 \times 5 = 1.875$, distance between rivets, $1\frac{3}{4}$ inches.
$.375 \times 5\frac{1}{2} = 2.062$, quantity of lap, 2 inches.
$.375 \times 5\frac{1}{2} = 2.062 + \frac{2}{3} = 3.437$, quantity of lap for double joint, $3\frac{1}{2}$ inches.

.75, 1.68, 1.87, 2.06, and 3.43, are, therefore, the proportionate quantities necessary to form the strongest steam or water tight joint on plates $\frac{3}{8}$ of an inch thick." *

DIVISION FOURTH.—FRICTION AND FORCE.

454. Section First — *Friction.* — In commencing to move one body upon another, however well polished the surfaces may appear to be, we find that a certain amount of force is required to change the condition of the body from a state of rest to that of motion, and that a certain further force is requisite to continue or keep up the motions so commenced. The resistance thus observed, one body moved over the surface of another under pressure, is called "friction;" that resistance which is required to overcome the state of rest, and convert it into motion, being known as the "friction of quiescence;" that which is required to keep up the motion being termed the "friction of motion."

455. In view of the importance of a right knowledge of the laws which regulate the effects of friction, various scientific men have from time to time instituted elaborate experiments, from which might be deduced practical rules of value to the mechanic. Among the authorities best known in this department of science we may name Coulomb, Rennie, and Morin. The experiments of the latter, which were carried out at the expense of the French Government, are the most complete of any yet instituted; and the results, which may be received with

* *Useful Information for Engineers*, p. 281.

great confidence, have afforded deductions which are now accepted as correct by nearly all practical men.

456. The experiments of M. Morin showed the friction of two surfaces, which have been for a considerable time in contact, to be different in amount and nature from the friction of surfaces in continuous motion; the friction of quiescence being subject to variation and uncertainty not observable in the friction of motion. "This variation," remarks Professor Moseley (*Mechanical Principles of Architecture and Engineering*, p. 146), does not appear to depend upon the *extent* of the surfaces of contact, in which case it might be referred to adhesion," for with different pressures, the ratio of the friction to the pressure —or the co-efficient of friction, as it is called—varied greatly, although the surfaces of contact were the same. (Thus, in the case of oak upon oak, with parallel fibres, the co-efficient of the friction of quiescence varied under different pressures upon the same surface from .55 to .76.) "The uncertainty which would have been introduced into every question of construction by this consideration, is removed by a second very important fact developed in the course of the same experiments. It is this, that by the slightest *jar* or *shock* of two bodies in contact, their friction is made to pass from that state which accompanies quiescence to that which accompanies motion; and as every machine or structure, of whatever kind, may be considered to be subject to such shocks, or imperceptible motions of its surfaces of contact, it is evident that the state of friction to be made the basis on which all questions of statics are to be determined, should be that which accompanies motion." The laws of friction, which we shall shortly state, "have been shown by the experiments of Morin to obtain, in respect to that friction which accompanies motion, a precision and certainty never before assigned to them; they have given to all our calculations in respect to the theory of machines (whose moving surfaces have attained their proper bearings, and been worn to their natural polish), a new and unlooked-for certainty, and may probably be ranked amongst the most accurate and valuable of the constants of practical science."

457. The following are the "laws" of friction, as stated by Professor Moseley: "(1.) That the friction of motion is subject to the same laws with the friction of quiescence (about to be stated), but agrees with them more accurately; that under the same circumstances of pressure and contact it is nevertheless different in amount. (2.) That when no unguent is interposed, the friction of any two surfaces (whether of quiescence or of motion) is directly proportional to the force with which they are pressed perpendicularly together (up to a certain *limit* of that pressure per square inch), so that for any two given surfaces of contact there is a constant ratio of the friction to the perpendicular pressure of the one surface upon the other. Whilst this ratio is thus the same for the same surfaces of contact, it is different for different surfaces of contact. The particular value of it in respect to any two given surfaces of contact is called the *co-efficient* of friction in respect to these surfaces. (3.) That when no unguent is interposed, the amount of the friction is in every case wholly independent of the *extent* of the surfaces of contact, so that the force with which two surfaces are pressed together being the same, and not exceeding a certain *limit* (per square inch), their friction is the same, whatever may be the extent of their surfaces of contact. (4.) That the friction of motion is wholly independent of the velocity of motion. (This result, of so much importance in the theory of machines, is fully established by the experiments of M. Morin.) (5.) That where unguents are interposed, the co-efficient of friction depends upon the nature of the unguent, and upon the greater or less abundance of the supply. In respect to the supply of the unguent, there are two extreme cases—that in which the surfaces of contact are but slightly rubbed with the unctuous matter (as, for instance, with an oiled or greasy cloth), and that in which, by reason of the abundant supply of the unguent, its viscous consistency, and the extent of the surfaces in contact in relation to the insistent pressure, a continuous stream of unguent remains continually interposed between the moving surfaces, and the friction is thereby diminished, as far as it is capable of being diminished, by the interposition of the particular unguents used. In this state the amount of friction is found (as might be expected) to be dependent rather upon the nature of the unguent than upon that of the surfaces of contact. Accordingly, M. Morin, from the comparison of a great number of results, has arrived at the following remarkable conclusion, easily fixing itself in the memory, and of great practical value: '*That with unguents, hog's lard and olive oil, interposed in a continuous stratum between them, surfaces of wood on metal, wood on wood, metal on wood, and metal on metal (when in motion), have all of them very nearly the same co-efficient of friction, the value of that co-efficient being in all cases included between .07 and .08. For the unguent tallow, the co-efficient is the same for the other unguents in every case, except in that of metals upon metals. This unguent appears, from the experiments of Morin, to be less suited to metallic substances than the others, and gives, for the mean value of its co-efficient under the same circumstances, .10.*'" *

458. The following is a table of the co-efficients of friction for various surfaces used in machine construction. In these experiments the surfaces, after having been smeared with an unguent, were wiped so that no interposing layer of the unguent prevented their intimate contact.

Surfaces of Contact.	Friction of Motion co-efficient.	Friction of Quiescence co-efficient.
Oak upon oak, the fibres being parallel to the motion,	0.108	0.390
Do., the fibres perpendicular,	0.143	0.314
Oak upon elm, the fibres parallel,	0.136	
Elm upon oak, do.	0.119	0.420
Beech upon oak, do.	0.330	
Elm upon elm, do.	0.140	
Wrought-iron upon elm, do.	0.138	
Wrought-iron upon wrought-iron, do.	0.177	
Cast-iron upon wrought-iron,	0.143	
Wrought-iron upon brass,	0.160	
Brass upon wrought-iron,	0.166	
Cast-iron upon oak,	0.107	0.100
Cast-iron upon elm, the unguent being tallow,	0.125	
Do. do., hog's lard and black lead,	0.137	
Elm upon cast-iron, fibres parallel,	0.135	0.098
Cast-iron upon cast-iron,	0.144	
Do. upon brass,	0.132	
Brass upon cast-iron,	0.107	
Brass upon brass,	0.134	0.164
Copper upon oak,	0.100	
Yellow copper upon cast-iron,	0.115	
Leather (ox-hide) well tanned upon cast-iron wetted,	0.229	0.267
Do. do. upon brass wetted,	0.244	

* *Mechanical Principles of Architecture and Engineering*, p. 142.

459. M. Morin was the first to observe the distinction between the friction of surfaces between which no unguent was interposed, those which are merely unctuous, and those between which a uniform stratum of the unguent is interposed. The differences between his experiments and those of M. Coulomb are considered to have arisen from those of the latter not having been carried out with sufficient care. Thus, the slight unctuosity arising from the greasy hand of a workman passed over the surface, was found to cause a considerable difference in the co-efficient of friction. Thus, in the case of surfaces of oak rubbed with dry soap, and thoroughly wiped, showing no traces of the unguent, the friction was reduced to the extent of two-thirds, the co-efficient being reduced from 0.478 to 0.164. Where surfaces were rubbed or moved in contact without unguents, the effect was to wear down the surfaces, black particles continually arising, which had to be removed from time to time; whereas by the use of an unguent this wearing away ceased, and in place of new contacts of surfaces being produced by the wearing away, the same surface remained, the continued motion giving a higher polish.

460. The following is a table of the co-efficients of friction of plane surfaces with unguents interposed. In these experiments " the extent of the surfaces bore such a relation to the pressure as to cause them to be separated from one another throughout by an interposed stratum of the unguent."

Surfaces of Contact.	Friction of Motion.	Friction of Quiescence.	Unguent.
Oak upon oak fibres parallel,	0.164	0.440	Dry soap.
Do. do.	0.075	0.160	Tallow.
Do. do.	0.067		Hog's lard.
Do. do. fibres perpend.	0.083	0.254	Tallow.
Do. do.	0.072		Hog's lard.
Do. do.	0.250		Water.
Oak upon elm, fibres parallel,	0.136		Dry soap.
Do. do. do. .	0.073	0.178	Tallow.
Do. do. do. .	0.066		Hog's lard.
Oak upon cast-iron do. .	0.080		Tallow.
Do. wrought-iron, do. .	0.098		...
Beech upon oak, do. .	0.055		...
Elm upon oak, do. .	0.137	0.411	Dry soap.
Do. do. do. .	0.070	0.142	Tallow.
Do. do. do. .	0.060		Hog's lard.
Elm upon elm, do. .	0.139	0.217	Dry soap.
Do. cast-iron, do. .	0.066		Tallow.
Wrought-iron upon oak, do. .	0.256	0.649	Greased, and saturated with water.
Do. do. do. .	0.214		Dry soap.
Do. do. do. .	0.085	0.108	Tallow.
Do. upon elm, do. .	0.078		Tallow.
Do. do. do. .	0.076		Hog's lard.
Do. do. do. .	0.055		Olive oil.
Wrought-iron upon cast-iron,	1.103		Tallow.
Do. do.	0.076		Hog's lard.
Do. do.	0.066	0.100	Olive oil.
Wrought-iron upon wrought-iron, . . .	0.082		Tallow.
Do. do.	0.081		Hog's lard.
Do. do.	0.070	0.115	Olive oil.
Wrought-iron upon brass, .	0.103		Tallow.
Do. do.	0.075		Hog's lard.
Do. do.	0.078		Olive oil.

[Table *continued*.

Surfaces of Contact.	Friction of Motion.	Friction of Quiescence.	Unguent.
Cast-iron upon oak, . .	0.189		Dry soap.
Do. do.	0.218	0.646	Greased, and saturated with water.
Do. do.	0.078	0.100	Tallow.
Do. do.	0.075		Hog's lard.
Do. do.	0.075	0.100	Olive oil.
Cast-iron upon elm, do. .	0.077		Tallow.
Do. do.	0.061		Olive oil.
Do. do.	0.091		Hog's lard and plumbago.
Do. upon wrought-iron, .		0.100	Tallow.
Cast-iron upon cast-iron, .	0.314		Water.
Do. do.	0.197		Soap.
Do. do.	0.100		Tallow.
Do. do.	0.070	0.100	Hog's lard.
Do. do.	0.064		Olive oil.
Do. do.	0.055		Lard and plumbago.
Cast-iron upon brass, . .	0.103		Tallow.
Do. do.	0.075		Hog's lard.
Do. do.	0.078		Olive oil.
Copper upon oak fibres, parallel,	0.069	0.100	Tallow.
Yellow copper upon cast-iron,	0.072	0.103	Tallow.
Do. do.	0.068		Hog's lard.
Do. do.	0.066		Olive oil.
Brass upon cast-iron, . .	0.086	0.106	Tallow.
Do. do.	0.077		Olive oil.
Brass upon wrought-iron, .	0.081		Tallow.
Do. do.	0.089		Lard and plumbago.
Do. do.	0.072		Olive oil.
Do. upon brass, ...	0.058		...
Steel upon cast-iron, . .	0.105	0.108	Tallow.
Do. do.	0.081		Hog's lard.
Do. do.	0.079		Olive oil.
Do. upon wrought-iron, . .	0.093		Tallow.
Do. do.	0.076		Hog's lard.
Do. brass, ...	0.056		Tallow.
Do. do.	0.053		Olive oil.
Do. do.	0.067		Lard and plumbago.
Tanned ox-hide upon cast-iron,	0.365		Greased, and saturated with water.
Do. do.	0.159		Tallow.
Do. do.	0.133	0.122	Olive oil.
Tanned ox-hide upon brass, .	0.241		Tallow.
Do. do.	0.191		Olive oil.
Do. upon oak, .	0.29	0.79	Water.
Hempen fibres not twisted moving upon oak, the fibres of the hemp being placed in a direction perpendicular to the direction of the motion, and those of the oak parallel to it, ...	0.332	0.869	Greased, and saturated with water.
The same as above, moving upon cast-iron, . . .	0.194		Tallow.
Do. do.	0.153		Olive oil.

461. For the matter of the table on the following page, of the experiments of M. Morin on the "friction of gudgeons or axles in motion upon their bearings," we are indebted to Professor Moseley's work, referred to in par. 455, p. 158.

462. With reference to these experiments of M. Morin, Professor Moseley draws attention to the fact that they were made under insistent pressures, small as compared with the extent of the surface pressed, the pressures varying only from 14 lb. to 28 lb. per square inch. This must be borne in mind, as the

"experiments of Coulomb, and particularly the excellent experiments of Mr G. Rennie, carried far beyond those limits of insistent pressure (Mr Rennie's

Surfaces in Contact.	State of the Surfaces.	Co-efficient of Friction when the grease is renewed.	
		In the usual way.	Continuously.
Cast-iron axles in cast-iron bearings.	Coated with oil of olives, with hog's lard, tallow, and soft gom,	0.07 to 0.08	0.054
	With the same and water,	0.08	0.028
	Coated with asphaltum,	0.054	0.019
	Greasy,	0.14	"
	Greasy and wetted,	0.14	"
Cast-iron axles in cast-iron bearings.	Coated with oil of olives, with hog's lard, tallow, and soft gom,	0.07 to 0.08	0.054
	Greasy,	0.16	
	Greasy and damped,	0.16	
	Scarcely greasy,	0.19	
Cast-iron axles in lignum vitæ bearings.	Without unguent,	0.18	
	With oil or hog's lard,		0.090
	Greasy with ditto,	0.10	
	Greasy, with a mixture of hog's lard and molybdæna,	0.14	
Wrought-iron axles in cast-iron bearings.	Coated with olive oil, tallow, hog's lard, or soft gom,	0.07 to 0.08	0.054
Iron axles in brass bearings.	Coated with oil of olives, hog's lard, or tallow,	0.07 to 0.08	0.054
	Coated with hard gom,	0.09	
	Greasy and wetted,	0.19	
	Scarcely greasy,	0.25	
Iron axles in lignum vitæ bearings.	Coated with oil or hog's lard,	0.11	
	Greasy,	0.19	
Brass axles in brass bearings.	Coated with oil,	0.10	
	" hog's lard,	0.09	
Brass axles in cast-iron bearings.	Coated with oil or tallow,		0.045 to 0.052
Lignum vitæ axles ditto.	Coated with hog's lard,	0.12	
	Greasy,	0.15	
Lignum vitæ axles in lignum vitæ bearings.	Coated with hog's lard,		0.07

experiments were carried, in some cases, to from 5 cwt. to 7 cwt. per square inch), have fully shown the co-efficient of the friction of quiescence to increase rapidly from some limit attained long before the surfaces abrade. In respect to some surfaces—as, for instance, wrought-iron upon wrought-iron—the co-efficient nearly tripled itself as the pressure advanced to the limits of abrasion."

463. In par. 464 we give a table by Mr Rennie, showing the co-efficients of friction under different pressures. These have reference only to the friction of quiescence; but Professor Moseley is of opinion that "it seems probable that the co-efficient of friction of motion remains constant under a wider range of pressure than that of quiescence. It is, moreover, certain that the limits of pressure, beyond which the surfaces of contact begin to destroy one another or to abrade, are sooner reached when one of them is in motion upon the other

than when they are at rest: it is also certain that these limits are not independent of the velocity of the moving surface."

464. The following is the table of Mr Rennie referred to in the preceding paragraph :—

Pressure per Square Inch.	Co-efficients of Friction.			
	Wrought-Iron upon Wrought-Iron.	Wrought-Iron upon Cast-Iron.	Steel upon Cast-Iron.	Brass upon Cast-Iron.
32.5 lb.	.140	.174	.166	.157
1.66 cwt.	.250	.275	.300	.225
2.00 "	.271	.292	.333	.219
2.33 "	.285	.321	.340	.214
2.66 "	.297	.329	.344	.211
3.00 "	.312	.333	.347	.215
3.33 "	.350	.351	.351	.206
3.66 "	.376	.353	.353	.205
4.00 "	.376	.365	.354	.208
4.33 "	.395	.366	.356	.221
4.66 "	.403	.366	.357	.223
5.00 "	.409	.367	.358	.233
5.33 "	...	.367	.359	.234
5 66 "	...	.367	.367	.235
6.00 "	...	.376	.403	.233
6.33 "	...	.434	...	.234
6.66 "	...	...	...	.235
7.00 "	...	...	...	.232
7.33 "	...	...	...	.273

465. With respect to the different unguents, Mr Rennie found, from a mean of experiments with axles in motion and under different pressures, "that with the unguent tallow, under a pressure of from 1 to 5 cwt., the friction did not exceed $\frac{1}{36}$th of the whole pressure; when soft soap was applied, it became $\frac{1}{31}$th; and with the softer unguents applied, such as oil, hog's lard, &c., the ratio of the friction to the pressure increased; but with the harder unguents, as soft soap, tallow, and anti-attrition composition, the friction considerably diminished."

466. *The practical deductions* from the investigation given in paragraph 463 may here be summed up: (1.) Friction is independent of the extent of surface —that is, it does not increase with the increase of rubbing surfaces. Small bearings, or journals, or surfaces in rubbing contact, wear more rapidly than when made large; hence, by increasing the surfaces, we increase their durability, but do not increase the power absorbed by friction. (2.) Friction is independent of velocity, so far at least as regards the friction on a given extent of surface: thus the friction of a shaft, during each revolution, is the same when revolving twenty times as when revolving five times a minute. Friction, however, is not independent of velocity when time is considered: thus, placing the friction of each revolution of a shaft which revolves twenty times a minute as 1, by increasing the revolution to sixty per minute the friction per minute is trebled, and represented by 3. The friction of each revolution of a revolving shaft has therefore a constant value, while the friction of any given time, as an hour or minute, increases with the velocity; hence, a machine wears out the quicker, the greater the velocity with which it is worked, although the friction of *any one revolution* is not increased by the increase of revolutions. (3.) Friction increases in proportion to the pressure: thus, with double pressure there

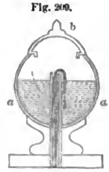
is double friction, with treble pressure treble friction, and so on. (4.) When unguents are employed, the nature of those applied must be regulated by the pressure, or the insistent weight; the greater the pressure, the harder should be the unguent (see par. 465). The office which lubricating agents have to perform is to prevent the rubbing surfaces coming into contact. Their efficiency is therefore proportional to their viscidity, although care should be taken not to choose a lubricating agent the viscidity of which is greater than that amount necessary to keep the surfaces out of contact: when the viscidity is too great, an additional resistance may be created.

467. The following is a recipe for making Booth's Patent Railway Axle Grease, from Weale's *Engineer's Pocket-Book:* "Water 1 gal., clean tallow 3 lb., palm-oil 6 lb., common soda ½ lb.; or, tallow 8 lb., palm-oil 10 lb." The mixture to be heated to about 210° Fahr., and well stirred till it cools down. Another recipe for axle-grease we borrow from Adcock's *Engineer's Pocket-Book for* 1857: "In a small boiler dissolve from a ½ cwt. to 60 lb. of soda in about 3 gallons of water; in a 60-gallon boiler melt tallow, and to it add palm-oil, each in quantity according to season, as hereinafter stated. As soon as the mixture boils, put out the fire, and let the mixture cool down gradually, frequently stirring it while cooling. When reduced to blood-heat, run it off through a sieve into the solution of soda, stirring it well the while to insure perfect commixture. Proportions of tallow and palm-oil: in summer weather, tallow 1 cwt. 3 qrs., palm-oil 1 cwt. 1 qr.; in winter, tallow 1 cwt. 1 qr., palm-oil 1 cwt. 3 qrs.; in spring and autumn, tallow 1 cwt. 2 qrs., palm-oil 1 cwt. 2 qrs."

468. In using oil for the lubrication of machinery, care should be taken to insure a good quality. In the manufacturing districts, so important a matter is the choice of good oil that "tests" are regularly applied to ascertain its value. It is evident that, in such large establishments as are there existing, a large expenditure of power will be required when the oil is of inferior quality, having a tendency to "drag." Sperm is used largely in these districts; and "mineral oil," manufactured from a peculiar quality of bituminous coal, is also highly thought of.

469. In figs. 160, 161, and 164 we have shown a usual method of applying oil to movable joints—a tapered hole being generally bored through the cap of the pedestal, as at *k*, fig. 160, and at *t*, fig. 161, or to the end of a vertical spindle, as at *h*, fig. 164; into this the oil is poured from an oil-can as desired. As the supply of oil to the bearings is thus dependent upon the care of the attendant, and is consequently liable to frequent fluctuations, if not in many cases to total stoppage, a lubricator, which will act at all times, has been a desideratum among engineers, to meet which numerous contrivances have been introduced from time to time. A simple contrivance is to attach an oil-cup or small vase *a a*, fig. 209, to the bearing, a pipe *c* leads from the interior of this to the journal. Down this a skein of cotton or wool is placed, one end of which rests in the oil in the vase; the oil is thus supplied to the journal by capillary attraction. The supply to the journal is constant so long as the vase is supplied with the oil; but no regulation can be attempted by this in proportion to the requirements of the machine—the supply being constant, whether the engine is standing or working, or going fast or slow. The top of the vase is at *b*. A method of overcoming this objection was introduced by Mr Barton, which consisted in the employment of a conical plug-tap like that of our ordinary stopcock, on one side of which he placed a small spherical aperture calculated to contain a drop of oil. So long as the supply of oil was

Fig. 209.

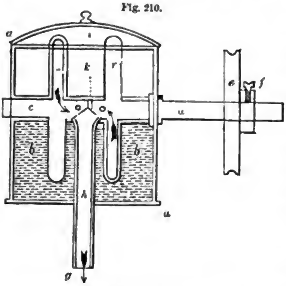


LUBRICATOR FOR SHAFTS —¼ SIZE.

maintained to the vase, and this cup remained uppermost in the tube connecting the vase to the bearing, no oil was supplied to the bearing; but on turning the tap half a revolution, the spherical cup was reversed, and the oil contained in it was discharged on the journal. To render it self-acting, and to stop its supply when the motion of the engine or machine ceased, all that was necessary to be done was to connect a ratchet-wheel to the continuation of the plug-tap, and work this ratchet from the shaft which required lubrication.

470. In fig. 210 we give a section of Tidmarsh's (23 Foxley Road, Kennington, Surrey, London) self-acting lubricator or oil-cup, which enjoys a high reputation for efficiency and cheapness.

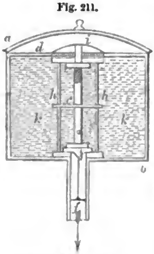
Fig. 210.



TIDMARSH'S SELF-ACTING LUBRICATOR.

471. Fig. 210 represents a vertical section of one form of lubricator: *a a* is the box cylinder, or vase of metal or glass containing the oil, *b b* the oil or lubricating material, which is raised or elevated by four tubular arms or spoons *r r*, and conveyed into the cylindrical end of driving-spindle *c d*, and then passes through the perforation *k* and the tube *h* to the bearings or other surface to be lubricated. The whole four arms can be used, *or one* only, according to the space to be lubricated; being screwed in, they can easily be turned round so as to come up backwards, they then take up no oil; they are screwed into the hollow driving-spindle *c d*, which works through the cylinder vase or oil-cup, having a button or washer to keep it in its proper position within the cup; the driving end of this spindle outside the cup has a flat side, to allow the pulley or rigger *e* to be moved along and set at any required distance by the pinching-screw *f*—the pulley is driven by a band from the nearest source of motion: *k* is the perforation which allows the oil to be conveyed from the hollow arms or spoons *r r*, through the vertical stem *h*, to the point where it is required; the hollow spindle is provided with a stop or washer, fixed between the hollow arms, to prevent the oil raised by the forward-motion spoon passing down the back-motion spoon: *i* is the top of the cylinder or vase. To be set in working order, this lubricator only wants the tube *g* at the bottom fixed in the oil-hole of the bearing, and a small band of catgut or string placed round the pulley *e* and attached to the nearest shaft to give motion. The price of this form is 10s.

Fig. 211.



TIDMARSH'S HAND-LUBRICATOR.

472. In fig. 211 we illustrate a form of lubricator by the same inventor, by which the oil is regulated by hand from 1 drop to 100 drops per minute: *a b* the vase or cup containing the oil *k k*; *d* the button, through which the screw *i* works in order to raise the valve *j* to allow the oil to pass down the tube *f* to the moving surfaces requiring lubrication; *i* the index or thumb-screw, by which the supply of oil is regulated; *c* a guide-plate attached to the valve and spindle *j*; *h h* pillars or standards on which the guide-plate works. To set this lubricator at work, the tube *f* is fitted into the oil-hole, and the cup filled with oil; the index-plate is then set at the

quantity required according to the figures thereon. The price, in glass or bronzed tin cups of this form, is 4s. 6d; in brass cups, 6s.; and without boxes, 3s. each.

473. SECTION SECOND—*Force.*—Mechanical work or effect is to overcome, during a definite period, a certain resistance or series of resistances, in estimating which the "pressure" exerted, the "distance" or the space passed through, and the "time" in which the distance is passed over, are all required to be taken into account. It is easy to enumerate various kinds of mechanical labour; the simplest, however, is to raise a perpendicular weight where inertia is not regarded. What is called the "unit" of mechanical effect is the power required to lift one pound "weight" through the "space" of one foot in a minute of time. This is called the English unit, the French being a kilogramme raised one metre high in a second. The unit of power adopted generally in England is what is called a "horse power," this having been assumed by Watt to be equal to 33,000 lb. raised 1 foot high per minute.

474. The principal sources of labouring force are the lower animals, man, wind, water, and steam. The three last, subject to mechanical laws, can be kept in action as long as required; the force of the lower animals and man depends upon a variety of circumstances, and can only be carried out at intervals. "What may be termed the amount of a day's work, producible by men and animals, is the product of the force exerted multiplied into the distance or space passed over, and the time during which the action is sustained. There will, however, in all cases be a certain proportion of effort, in relation to the velocity and duration, which will yield the largest possible product, or day's work, for any one individual, and this product may be termed the maximum effect. In other words, a man will produce a greater mechanical effect by exerting a certain effort at a certain velocity, than he will by exerting a greater effort at a less velocity, or a less effort at a greater velocity; and the proportion of effort and velocity which will yield the maximum effect is different in different individuals."

475. For the following table of the average amount of mechanical effect producible by men and animals, we are indebted to Johnson's *Book of Industrial Design*, &c.

NATURE OF THE WORK.	Mean Weight elevated, or effort exerted.	Velocity or Distance per second.	Mechanical Effect per second.	Duration per day.	Mechanical Effect per diem.
	lb.	feet.	lb. raised 1 foot high.	hours.	lb. raised 1 foot high.
A man ascending a slight incline, or a stair, without a burden, his work consisting simply in the elevation of his own weight,	143	.50	71.5	8	2,059.200
A labourer elevating a weight by means of a cord and pulley, the cord being pulled downwards,	40	.65	26.0	6	561.600
A labourer elevating a weight directly with a cord or by the hand, ...	44	.56	24.6	6	531.360
A labourer lifting or carrying a weight on his back, up a slight incline or stair, and returning unladen, . . .	143	.13	18.6	6	401.760

[TABLE *continued.*

Nature of the Work.	Mean Weight elevated, or Effort exerted.	Velocity or Distance per second.	Mechanical Effect per second.	Duration. per day.	Mechanical Effect per diem.
	lb.	feet.	lb. raised 1 foot high.	hours.	lb. raised 1 foot high.
A labourer carrying materials in a wheelbarrow, up an incline of 1 in 12, and returning unladen,	132	.06	8.5	10	306.000
A labourer raising earth with a spade to a mean height of 5 feet,	60	.13	7.8	10	280.000
ACTION ON MACHINES.					
A labourer acting on a spoke-wheel, or inside a large drum, at the level of the axis,	132	.50	66.0	8	1,900.800
Near the bottom of the wheel,	26	2.30	59.8	8	1,722.240
A labourer pushing or pulling horizontally,	26	1.97	51.2	8	1,474.560
A labourer working at a winch handle,	17½	2.46	43.0	8	1,238.400
A labourer pushing and pulling alternately in a vertical direction,	11	3.61	39.7	8	1,143.360
A horse drawing a carriage at an ordinary pace,	154	2.95	45.43	10	16,354.800
A horse turning a mill at an ordinary pace,	99	2.95	292.0	8	8,409.600
A horse turning a mill at a trot,	66	6.56	433.0	4½	7,014.600
An ox doing the same at an ordinary pace,	143	1.97	281.7	8	8,112.960
A mule do. do.	66	2.95	194.7	8	5,607.360
An ass do. do.	31	2.62	81.2	8	2,338.560

476. If we find that a machine only does a certain fraction of the work which it is required to perform, this fraction is called the "modulus" of the useful effect, the remainder being the amount lost by friction. Thus, if the work done is only two-thirds of that required, one-third is lost by friction, two-thirds being the modulus of the useful effect of the machine. Thus in working the screw-press two-thirds are lost by friction, so that one-third is the modulus of the screw-press. The endless screw loses in working one-half of its power by friction; its modulus is therefore only one-half.

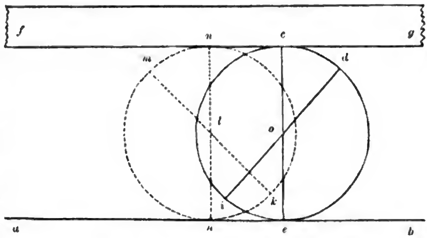
477. To ascertain the "modulus" of any machine, or, what is the same thing, the amount of working effect lost by friction, we use the dynamometer and the friction-brake. The dynamometer is employed in cases of draught, as ploughing, reaping, dragging of carts, &c.; the friction-brake where rotatory motion is employed. We shall describe these contrivances at the proper places, hereafter proceeding, for the present, to notice the mechanics of "carriage-wheels," and the principles of "draught."

478. The *roller* is the simplest and most accessible auxiliary in the hands of the common labourer or workman, to aid his energies when he has occasion to move heavy masses, as beams of wood or iron, or blocks of stone, over short distances; and how few of those, who are every day employing this mechanical agent, are likely to consider that, by means of it, they are moving the substance under transportation over *twice* the *space* that the roller itself has passed through. When the substance moved is borne *upon* rollers having an axle passing through them, as in the case of a wheel-carriage, the transported body either

rests upon the axle, or on a carriage attached to it; hence the velocity of its rectilineal motion must be the same as that of the axis of the roller, which, as is well known, passes over a space equal to the circumference of the roller or wheel in every revolution of the same. When the substance simply rests on the periphery of the roller or wheel, it will be easily seen, that for every revolution that the roller makes it will move over a space on the surface of the ground equal to its own circumference, and that while doing so, the substance which it bears along, will, in the same time, have applied to the roller a portion of its length equal to that circumference, and which will have passed *over* the roller; but the substance being entirely borne by the roller, must also partake of its progressive motion through space, and that at the same rate as the roller itself; hence the substance must have passed over double the space that the roller has done in a given time. This result will perhaps be more clearly understood by considering increments of the motions.

479. Let *a b*, fig. 212, be the surface of the ground on which a roller, represented by the circle *c d e*, is to roll, bearing the beam *f g*. If the beam be pushed in the direction of *g f*, every point in the arc *c d* of the roller will successively come in contact with corresponding points in the surface of the beam lying between *c* and *d*; during this process the circle will have moved in the direction *b a*, over a space *e h*, on the ground equal in length to the arc *i k* or *c d*, and the centre *o* of the circle will have moved over a like space *o l*, but the diameter *e c* will now have assumed the position *k m*, and *i d* the perpendicular position *h n*, the point *p* having moved to *n*, or through twice the space *o l*, or twice the arc *c d*; and the beam *g f* has in like manner moved through twice the length of the arc *c d*, equal to the space *p c n*, which is double of *o l* or *e h*. It results from this conclusion that the body must very soon pass beyond the roller; hence a constant succession of rollers must be applied in front of the moving body, and hence, also, the application of this species of carriage must in general be limited to short distances. But from the extreme simplicity of the apparatus, and if the bed on which the rollers move is of a uniform texture, an almost entire absence of friction is obtained, whereby very heavy masses may be moved with a comparatively small force, and we accordingly see this simplest form of carriage in almost daily application. It is further well known that this principle has been applied in modern times to the transport of immense masses, larger, perhaps, than ever were moved by the engineers of antiquity, however colossal their works may have been. The mass of rock that forms the pedestal to the statue of Peter the Great at St Petersburg, stands a noble monument of modern engineering, especially as regards its transport over a distance of four miles, achieved by the application of this principle: the rollers, however, in this case, were spheres of metal about 6 inches in diameter, and not cylinders, but this does

Fig. 212.



THE EFFECTS ON MOTION OF THE SIMPLE ROLLER.

not alter the principle of the motion. The subject is one of much interest, but it would be out of place to follow it up here, our object being more of an agricultural than an engineering character.

480. Though it is probable that the simple roller had succeeded the sledge, as a medium of transport for heavy bodies, in the early stages of society, it appears evident, from historical records, that the wheel and axle had been resorted to at a very remote period; for both in sacred and profane history we can trace their use through a period of not less than 3000 years. It appears very probable, also, that in the early application of the axle, it was adopted at first to combine two short rollers, which would have an advantage over the long roller, by avoiding, in their progress, much of the obstruction that the continuous roller must have met with. The transported body would then lie upon the axle, and to prevent its travelling over it, which it would do, though at a much slower rate, than under the arrangement shown by fig. 212, the transition is easy to round the axle, and confine it to turn in a box or bush attached to the body under transportation, which now, in fact, becomes the carriage. There is every reason to believe that this has been the original form of wheel-carriages; that is to say, the axle and the wheels moving together, the former being confined to turn within bearings attached to the body of the carriage, and the wheels short but solid cylinders of wood. This form of wheel and axle is not confined to antiquity; it has existed in Europe, in Britain, within the last century, and is yet to be met with in some remote regions. It is worthy of remark, that the wheel and axle of almost all railway carriages, whether of early or late construction, are upon this plan; and the most perfect of all wheel-carriages—the railway locomotive—is the same.

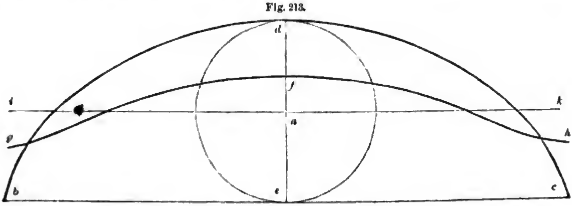
481. It might be urged from this last circumstance, that this being held as the best form of wheel and axle for railways, and especially the locomotive, that it ought also to be the best for all other wheel-carriages; but there are circumstances which render it applicable in the one case, and inadmissible in the other. In the railway carriage, it has been found by experience that the wheels and axles are less liable to derangement when turning *together* within a box or bush, than with the *wheel* turning upon the axle, though a carriage mounted in that way is not so well adapted to turn in a curve of short radius; but to obviate this, railways are now laid out with curves of very long radius. On the other hand, wheel-carriages for common roads and all domestic purposes would be extremely inconvenient if their wheels moved together, as they have very frequent occasion to turn in very narrow limits, which could only be done under great disadvantages were the axle and wheel to move together; but with wheels turning upon the axle, the greatest possible freedom of motion is afforded for turning in a small space; and, but for this difficulty, it appears yet undetermined whether or not the ordinary cart would be better adapted for its work, and the wheels more durable, were they fixed upon the axle. Be this as it may, the step from the fixed wheel and axle to the fixed axle and revolving wheel has been easy and obvious.

482. Though, in some barbarous cases, the rude form of wheel and axle is to be found in later times, there can be no doubt that in those countries where the arts flourished at an early period, the wheel and axle were employed under the same principle as we now see them in the present day; and this is another instance of the really small progress of human invention during a period of from two to three thousand years; but it must be admitted, that though we have not brought any new principle into operation, we have greatly improved in the details of the construction of wheel-carriages.

483. In considering the action of carriage-wheels in general, we have seen that, when applied as simple rollers, if the surfaces on which they roll were level, perfectly smooth and hard, and the roller also possessing the two latter qualities, there would be little or no resistance from friction, and the carriage or body would move with the least possible force. These circumstances not being attainable, and, from considerations of convenience, the wheels being placed upon an axle, it comes to be viewed under a change of circumstances: thus, though we may still conceive the wheels to move upon a surface that might present no obstruction to its forward motion, we have an element of resistance now introduced,—the friction caused by the wheel turning upon its axle; which, along with certain peculiarities connected with the subject, is first to be considered.

484. If we take the wheel as rolling upon a level plain, and its circumference being supposed a perfect circle, it presents several peculiarities. Let the circle *a*, fig. 213, represent a wheel rolling from *b* towards *c* on the level

Fig. 213.



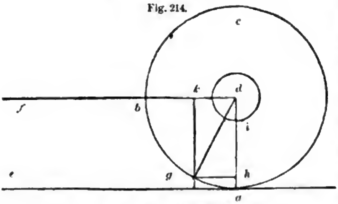
THE CURVES GENERATED BY A POINT RESPECTIVELY IN THE CIRCUMFERENCE OF A WHEEL AND ITS NAVE DURING ONE REVOLUTION OF THE WHEEL.

line *b c*; when it has made one revolution, its centre *a* will have moved through a space, and will have described a straight line *i k* in that space, in a vertical plane, equal to the circumference of the wheel; that point of the circumference, also, from which it started on the level plane, will have described the beautiful and highly important curve the cycloid *b d c*, having its base *b c* equal to the circumference of the wheel, and its height *d e*, or axis of the cycloid, equal to the diameter, while the length of the curve *b d c* has been found to be equal to *four times* the diameter of the wheel. When the describing point is taken anywhere within the circumference of the circle or wheel, the curve described, though a modification of the cycloid, assumes a somewhat different character. Suppose a point in the circumference of the *nave* of the wheel, as at *f*, the curve generated by this point will be inflected, as *g f h*, crossing the straight line described by the central point of the circle twice in the course of one revolution of the wheel; but the base of any curve that can be so generated, will be always equal to the circumference of the primary circle. It is foreign to the objects of this work to trace the remarkable properties of the cycloid; suffice it to say, that they are highly important in the theoretical consideration of dynamics, and have been investigated and determined by the most eminent geometers; and we can thus see that even the mean and homely object—a cart-wheel—may have afforded data upon which some of the finest intellectual discoveries of the human mind have been based; for the investigation of this curve has occupied the attention of such men as Des Cartes, Pascal, and Huygens, to the latter of whom we owe the discovery of the remarkable property, that in a cycloid (in a position inverted to that of our fig. 213), bodies let fall from *any* point of the curve will reach the lowest point of it at the same time.

485. As regards the *theory* of the *wheel*, applied practically in agricultural carriages, we have, first, to notice the manner in which it is affected by the draught, the resistance of the road, and the friction at the axle. We have seen that wheels in moving along a level road have their centres always preserved at the same height; and from the manner in which the carriage is attached to the axle, and the draught to the carriage, we know that the ultimate effect of the latter results in its direction being nearly in a straight line drawn from that point of the shafts where they are suspended from the back of the horse on to the centre of the axle. This line may in some cases be horizontal, as in the case of a horse of low stature; but in most cases it forms an angle with the horizon of from 5° to 12°, and its true position is such as to bring that point of the shafts to which the draught-chains are attached into a straight line between the centre of the axle and the hook of the horse's collar, and in the present consideration, it will be sufficient to assume that the line is horizontal. If we now suppose a carriage loaded to the ordinary extent, and bearing upon the axle, which again rests upon the lower side of the box or bush of the wheel, we have the following results.

486. Let fig. 214 exhibit the above arrangement; *a b c* is the wheel, *d* the axle, *a e* the horizontal plane, on which the wheel moves in the direction of the line of traction *d f*. If the plane *a e* is truly level and smooth, the wheel will be put in motion with a very small force; and if we suppose all friction at the axle destroyed, it goes on without stopping, as there would be no resistance; but such a state is not attainable in practice, and that from external causes,—the resistance of the air, the impossibility of procuring a surface devoid of inequalities, and, consequently, any attainable surface will be productive of friction or resistance. A wheel, with a cylindrical edge, rolling on a plane, whether horizontal or inclined, as it does not *slide* upon that plane, but makes simply a succession of contacts, cannot be said to meet any resistance from friction: the chief resistance it encounters, then, is from inequalities of surface, which may induce a constant succession of ascents of the wheel and its load over these inequalities, with intermitting descents of the same; or, as in the case of a soft and yielding surface, it will amount to a constant ascent, but still without *friction*, a term which can only be applied to that species of resistance arising from the motion of one body *sliding* upon, or through another. The chief source of friction, then, in the wheel, is that which is generated between the axle and its bush; the amount of this friction will depend upon the relative diameter of the wheel and its axle, and upon the nature of the materials of the axle and the bush, and also the state of their surfaces. As regards the first, if the radius of the wheel *d a*, fig. 214, is taken at 28 inches, and that of the axle *d i* at 1¼ inches; and a force applied to the axle in the direction *d f*, while the whole pressure of the load rests on the point *i*, where the friction is produced: if the axle is thus drawn forward by the force *d b*, the wheel is resisted by its contact with the ground compelling it to roll along, and thus there is produced

Fig. 214.



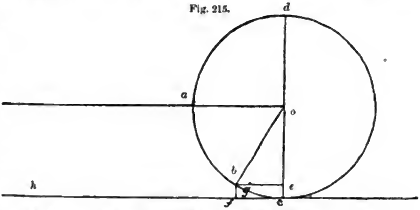
THE FRICTION OF CARRIAGE WHEELS.

the sliding motion at i upon the axle; but the radius $d\,a$ acts in this case as a lever of advantage, in favour of the force $d\,b$, in the proportion of $d\,a$ to $d\,i$, or the circumference of the wheel to the circumference of the axle. For when the entire circumference of the wheel has been applied to the surface of the ground, that of the axle only has been applied to the surface of the bush; and as the diameter of the axle may be taken at $\frac{1}{22}$ of the wheel, the amount of friction acting in resistance to $d\,b$ the draught, will be only $\frac{1}{22}$ of the entire resistance, whatever that may be.

487. Much uncertainty prevails as to the value or amount of friction in relation to the load: while some experimenters have found it not to exceed $\frac{1}{40}$, with a surface of iron running upon brass, and well oiled, others have made it as $\frac{1}{8}$ or $\frac{1}{10}$ of the load; and as cart-grease is not usually the most unctuous of substances, we with safety take it at $\frac{1}{16}$ for cart-axles. Let the load, then, including the cart, be 25 cwt.; $\frac{1}{16}$ of this is 175 lb. for the absolute resistance from friction at the axle; but we have just shown above that the leverage of the wheel and axle reduced it to $\frac{1}{22}$ or $\frac{175}{22}=8$ lb. nearly, as the actual value of the friction at the axle, resisting the force in the direction $d\,b$, fig. 214, or, in other words, the draught; but here it must be understood that the axle and bushes must be in the best condition, the former steeled on the lower side and turned, or turned and case-hardened, and the bush smooth and hard. We see from this reasoning, that the friction of the axle produces but a small portion of the resistance; for taking the draught at an average of 160 lb., which is known, both from theory and experiment, to be about the amount of a horse power, moving at $2\frac{1}{2}$ miles per hour, the resistance of the axle forms only $\frac{1}{20}$ of this draught.

488. It is from the surface of the road, then, that we are to find the remaining $\frac{19}{20}$ of the resistance; and this will appear sufficiently obvious from a consideration of fig. 215. The resistance to the motion of the wheel, it has been stated, arises from inequality of the surface over which it rolls, and this may be shown by taking the point b as an obstacle coming under the wheel, and over which the wheel and load must be raised. Most of those who have treated this part of the subject, have usually demonstrated only the relation of one wheel to another, in terms of their diameter or their radius, and the resistance respectively encountered in passing over any obstacle, viewing the wheel simply as a roller, within which the whole load is concentrated. Thus, if the circle $c\,a\,d$ represents a wheel rolling on the horizontal line $c\,h$, and opposed by an obstacle at b, while it is drawn forward in the direction $o\,a$ by a certain force, this force will act with a leverage equal to $o\,e$ in overcoming this obstacle, while the weight of the load on the wheel opposes it with a leverage that is represented by the line $e\,g$. By construction, b is equal to $\sqrt{d\,c} \times \sqrt{e\,c}$;* and supposing the obstacle to be the same for all heights of wheel, $b\,f = e\,c$ will be constant, while $d\,e$ varies as the diameter, but $b\,e$ will increase only as the square root of $d\,e$, which, in all ordinary cases, may be held as equal to the diameter, and

Fig. 215.



THE EFFECT OF RESISTANCE FROM OBSTACLES ON THE SURFACE OF THE ROAD

* *Euclid*, iii. 35.

therefore the force required to move the wheel over the obstacle b will be inversely as the square root of the diameter of the wheel, nearly: for example, taking the common cart-wheel of 56 inches diameter, its square root is 7.5 nearly, which may be called unity; and take another wheel of 68 inches, or 1 foot higher, the square root of this is 8.2, and, compared with the first, is 1.09 to 1. If a force of traction, therefore, of 300 lb. were required to overcome this obstacle with wheels of 56 inches, a force of 275 lb. would overcome it with wheels 1 foot more in diameter, for as $1.09 : 1 :: 300 : 275$; this is supposing that in both cases the force is supplied horizontally from the centre of the axle.

489. The foregoing example is still only applicable to the case of a roller or wheel having the load concentrated within it, or otherwise placed right over its axle; but as this does not apply with exactness to a two-wheeled cart having the load disposed in such a manner as to throw its centre of gravity about 5 inches before the axle, we shall now take a more practical case, and consider it under this last circumstance.

490. Referring still to fig. 215, suppose that the wheels are moving over a surface that yields to the pressure so as to sink $\frac{1}{2}$ inch into the road, which may hence be considered as presenting a constant obstacle of one-half inch in height. This will give us $d\ e$ equal to $55\frac{1}{2}$ inches, and $e\ c$ one-half inch, the $\sqrt{55.5} \times \sqrt{.5} = 5.2$ inches $= b\ e$, and if the force of traction is applied at o in a horizontal direction, it gives the lever $o\ e = \frac{d\ c}{2} - c\ e = \frac{56}{2} - .5 = 27.5$ inches, while the resisting arm is 5.2 inches, making the power to the resistance as 27.5 to 5.2. The entire load being supposed 25 cwt., of which, from its disposition on the length of the lever formed by the body and shafts of the cart, from $\frac{1}{18}$ to $\frac{1}{20}$ is borne by the horse, the remainder by the axle: the load on the horse may therefore be taken at $\frac{25}{19} = 1.3$ cwt. nearly, leaving on the axle 23.7 cwt.; and this, increased by the weight of the wheels and axle, will make the amount of resistance about 28 cwt. But as the power of the lever $o\ e$ is to that of $e\ b$ as 27.5 to 5.2, or 5.3 to 1 nearly, then $\frac{28}{5.3} = 5.283$ cwt., or rather above $5\frac{1}{4}$ cwt. for the force of traction during the *first instant* of raising the wheels with this load over an obstacle $\frac{1}{2}$ an inch high. This is supposing that both wheels meet the obstacle, and that it is perfectly incapable of being depressed. If only one wheel meet it, then the resistance is reduced one-half, and the traction one-half; and if the obstacle arises from a uniform sinking of the surface by the pressure of the wheels, then both meet the obstacle; but as it suffers depression while the load is in the act of being raised, the maximum of resistance will again not exceed one-half of the result quoted above, or 2.625, and will vary downward according to the state of the road, till it reach the minimum force of traction, which cannot be estimated at less than 120 lb.

491. From the foregoing remarks we have seen that the friction at the axle is inversely as the diameters of the wheel and the axle, but, at the same time, that friction is so small in amount, that any practicable addition to the diameter would produce such a mere fraction of reduction upon the total resistance as to be of no importance in practice. On the other hand, though the resistance arising from impediments on the surface of the road affects wheels to an amount greatly beyond the friction at the axle, to not less than 20 times the amount of the other, and though the reduction of resistance increases in a much lower ratio with the diameter, being inversely as the square roots nearly, yet even this, as we have seen, would only increase the advantage by $\frac{1}{12}$ of the whole resistance, or as $1 : 1.09$ as above, with wheels of 1 foot greater

diameter,—an advantage not to be compared with the many inconveniences that would attend such an increase of height in the wheels.

492. The present seems an appropriate place to introduce a few remarks on what may be called the "philosophy of loading of wheel-carts," or the disposition of the load.

493. *The Disposition of the Load.*—It is always of importance to husband well the energies of the horse; and in no case is it more necessary than in the cart-horse. The disposal and management of the loaded cart has frequently occupied attention: by some it has been treated in a becoming manner, though frequently too abstruse for the agricultural mechanic, or general agricultural reader. In others, the lucubrations are neither rational nor mathematical, though professing to be the latter, but exhibit an attempt to set at nought the received statical laws, and partially to annihilate matter, or at least its effects, as evinced in the principle of gravitation, a curious example of which is to be found in a modern periodical. We do not stop to point out the errors here alluded to, but proceed to a simple consideration of the subject.

494. To facilitate the arrangement of the load in the two-wheeled cart—described hereafter in the section *Construction of Carts*, Book Second—the practice has been to place the cart upon the axle, in a position that places $\frac{4}{7}$ of the body before the axle, and $\frac{3}{7}$ of it behind. Whether this has been deduced from calculation or experiment, cannot now be determined; but one thing is certain, that the above proportion seems to suit all purposes, and what is more, it yields, by calculation and experiment, a result which loads the horse in the shafts with a fair degree of pressure, and such as he is quite capable of supporting through a moderate journey. The amount of this load on the back of the horse has frequently been very much overrated; and few practical people having a clear conception of its amount, it may be satisfactory to many that the true state of the matter be made to appear.

495. The position of the caddy-bolts is usually determined in accordance with the above practice, or the following division affords the same result: To the length of the body-frame add half the slope of the front, or 2 inches; divide this whole length into two equal parts, and subdividing the back half into seven equal parts, the caddy-bolt holes will be in the first of these subdivisions, or at $\frac{1}{14}$ part of the whole length behind the central division. Thus, in the cart whose body-frame is 5 feet 4 inches, add 2 inches for the half slope of the front, making 5 feet 6 inches, or 66 inches in all. Half this is 33 inches, $\frac{1}{7}$ of which $=4.71$ inches, and $33+4.71=37.71$ inches, the length of that portion of the body that lies before the caddy-bolt, while the remaining 28.29 inches lies behind, being $\frac{4}{7}$ and $\frac{3}{7}$ as before. When the cart is loaded, therefore, there will be a preponderance of $\frac{1}{7}$ of the load before the axle on which the cart-body rests.

496. Taking the whole load at 21 cwt., $\frac{1}{7}$ of this is 3 cwt., or 336 lb., the preponderance of the load forward, on the supposition that it is uniformly distributed over the cart-body; but as the common practice places it more towards the front, the preponderance may, with more accuracy, be taken at 400 lb. Taking the weight of the cart-body, exclusive of the wheels and axle, at 5 cwt., and taking $\frac{1}{7}$ of this also, or 80 lb., and adding to this the effect of the shafts, with the iron mounting, which may amount to about 60 lb., and is to be considered as acting at the centre of gravity of the preponderating part of the load, we have an aggregate preponderance of $400+80+60=540$ lb. This quantity is to be supposed as distributed over that part of the body lying before the axle, and from the disposal of this part of the load, its centre of gravity will be at the distance of about 20 inches before the axle. Again, the shafts in this arrangement form

a lever of the second order, whose fulcrum is the axle, and the load is applied at the distance of the centre of gravity, 20 inches from the fulcrum, while the power (the horse's back) is applied at $4\frac{1}{2}+3$ feet, or thereby $=90$ inches from the fulcrum, giving the power a mechanical advantage of 90 to 20, or 4.5 to 1: the horse therefore bears $\frac{1}{4.5}$ part of the preponderating load, which, as we have seen, is 540 lb., $\frac{1}{4.5}$ part of which is 120 lb. for the pressure on the back of the horse. This calculation agrees perfectly with experience, for, by experiments on loaded carts with a dynamometer, the strain on the back-chain of the horse has been found to range from 100 to 140 lb., when the shafts were in the due working position.

497. From the want of a due consideration of the effect of the load as it presses on the horse's back, the results are frequently much exaggerated, and much uncalled-for pity and commiseration excited in behalf of the horse, by those who, not taking time to investigate, are led by their feelings into erroneous conclusions as to the amount of suffering which, in too many cases, is inflicted most unnecessarily upon that valuable animal by his careless and unthinking driver. But the direct load on the horse's back here established, is that due to travelling on a level road, and it is liable to variation when travelling on inclined roads, always to the inconvenience and suffering of the horse. In such cases the variation depends much on the nature of the substance composing the load. If it is of a nature to load high, the variation becomes the greater, in consequence of the centre of gravity being proportionally high; and the inclination of the cart-body and shafts following the rise or fall of the road, the position of the centre of gravity is thrown backward or forward: backward in ascending, thereby lessening the pressure on the horse's back; and forward in descending, increasing the pressure. These variations, though no doubt a source of inconvenience, have also been exaggerated; for we have found, from actual experiments, as well as from calculation of the effects, that in descending an inclination of road so great as 1 in 8, that the *increase* of pressure on the back of the horse is not more than $\frac{1}{3}$ of the pressure on a level road, the ultimate strain on the back-chain arising from such inclination being about 160 lb. This is, besides, a very extreme case, for few roads are now to be found with such a high gradient. There is good reason, therefore, to conclude that the additional strain on the back will seldom amount to 30 lb., except with loads of corn and hay, in which the centre of gravity is necessarily high. In ascending acclivities, the pressure on the back is *reduced* in nearly the same proportion as the increase upon declivities.

498. The inconveniences thus attending the variation of load in ascending and descending inclined roads, has given rise to numerous proposals for methods to equalise the pressure on the back. Hitherto, however, nothing of value has been discovered, in which the trouble and inconvenience attending the adjustment of the apparatus proposed, does not more than counterbalance any advantage that could be obtained from it. One of the most feasible plans proposed to achieve this, is to have the cart so placed on the axle that the whole cart-body, with its load, shall be made to slide a few inches backward or forward upon the axle, by means of a screw placed at the back of the cart, and may be turned by the hand. Such an apparatus may no doubt be rendered capable of effecting the intended purpose; but it would so encumber and break in upon the simplicity of the machine, besides requiring considerable attention, and all these to an extent that, it is to be feared, would not be compensated by advantages of equal value.

499. It will always be on descending inclinations of road that the horse will

be most distressed; and, from the comparatively small increase of load that is brought upon him in the descent, as has been already shown, it seems probable that what he suffers arises more from the cart with its load pressing him *forward*, than from the direct effect of gravity upon his back. If this view is correct, and there appears much reason to believe it, it would then be of greater moment to obtain a ready and efficient means of *retarding* the forward tendency arising from gravity, by the application of a *drag*, than by any attempt at shifting the load. This has been attempted by the action of the horse in *holding back* through the medium of the breeching-harness acting upon friction-blocks pressing against the edge of the wheel; but it seems very questionable if the method can be rendered sufficiently effective with safety to the horse. As a convenient means of dragging, there appears no method more simple and efficient than that which we have copied from our French neighbours, and is now applied with such success to omnibuses and gentlemen's carriages, namely, the lever, or the lever-and-screw drag, applied to the periphery of the wheels. This mode possesses most of the advantages required in an efficient and convenient drag, is easily managed, and not very expensive; neither would it incommode the ordinary working of the cart; and as it can only be required in hilly districts, or where roads are not well levelled, it could be laid aside or applied, according to the nature of the journey that might be in contemplation. Attempts have also been made to apply a drag on this principle to the nave of the wheel; but this has been, and always will be, a failure, owing to the comparative smallness of diameter, and consequent low velocity of the revolving surface against which the friction-blocks are pressed, affording but a small degree of friction, unless the levers are made very strong, and to act with great mechanical advantage. But these conditions involve two other disadvantages—the additional weight of a stronger apparatus, and the risk of fracture, arising from greater pressure being requisite to give it effect.

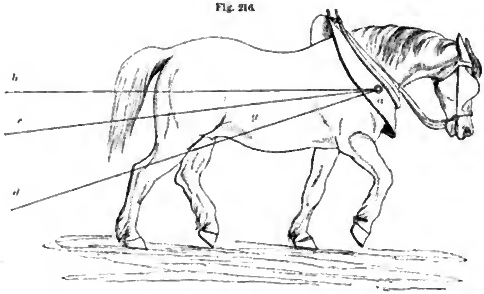
500. These considerations naturally lead us to consider the question of the *direction of the line-draught* of wheel-carriages. This is a point which is also deserving of consideration in its application to wheel-carriages; and in this view the structure of the horse, as an animal of draught, should be kept in mind. From the configuration of the skeleton in the horse, and his muscular system, we perceive at a glance that his form is adapted to produce a much greater effect in dragging a load than in carrying upon his body. In man the case is different. From the circumstance of his skeleton, in the lower extremities and trunk, being composed of parts superimposed, and forming a column, which, though furcated below, is only thereby rendered the more stable, he is capable, though greatly inferior in weight and mass, to bear a vertical load even surpassing that of a horse, while in dragging he is greatly inferior; and it is only by inclining his body from its upright natural position, that he is able to exert beyond a very moderate force in a horizontal or slightly-inclined direction. It is true that, if his body is once so far inclined as to admit of his gravity to bear with its maximum effect, while his limbs and vertebral column are brought to act in concert with his weight to resist a force of traction applied to his shoulders, he will, in such a position, produce a much greater effect, taking weight for weight, than a horse; and while a man will travel with a load on his shoulders equal to $\frac{2}{3}$ of his own weight, a horse will not do the same with more than $\frac{1}{3}$. But a horse will perform a journey with equal ease, and drag a load of twice his own weight, if placed in a two-wheeled cart. And hence we see the vast importance of the modern system of good roads and wheel-carriages, as compared with the state of things only a century ago, when roads, if

existing at all, were in a wretched state, and, consequently, much of the conveyance of goods and produce was performed by pack-horses—the load laid on the back of the horse. Now the useful effect of a horse may be estimated at six times that of the back-load practice.

501. In achieving these great improvements, advantage has been taken of the physical properties and conformation of the horse, especially that of his being more adapted for drawing than for carrying. But it has also resulted that, from his powers of draught depending in some degree upon his weight as well as upon his muscular energy, it is found advantageous to give to his weight an increased effect, either by direct application of a limited load upon his back, as in the case of the two-wheeled cart, or artificially, by causing the direction of the line of draught—as in the plough—produce indirectly a force in the direction of gravity, by the oblique direction of the draught. Thus we see, that in drawing the plough, while the horse is exerting a force of draught of 160 lb. to draw forward the plough, he is bearing, as a part of this result, a vertical pressure at or near his shoulders, arising from the direction of the trace-chains, which here lie at an angle of about 18°. Though this angle, in working the plough with horses of ordinary stature, is found convenient and effective, it does not follow that the same is requisite in all cases of draught; for, with due consideration to the comfort of the horse, it should vary with the weight and the supposed muscular powers of the different horses that may be employed; though, from the practical difficulties attending any attempt at such adjustment, it becomes necessary to adopt general principles, and to be satisfied with approximation. In no case, however, can it be otherwise than disadvantageous to the horse to make him draw horizontally; and much worse were the line of draught to incline upwards from his shoulders, as either of these would tend to deprive him of part of his natural weight.

502. It appears evident that, in order to give the horse full advantage of his own weight in pulling, the line of direction in which his force is applied should lie in a plane that would pass through the centre of gravity of his entire mass. This will be more clearly evident from fig. 216, representing a horse,

Fig. 216.



THE PRINCIPLES THAT DETERMINE THE ANGLE OF DRAUGHT.

with lines of draught extending from the hook of his collar, and which will serve to elucidate our position. The centre of gravity of the horse will lie about the position g, coinciding nearly with the line $a\ d$, forming an angle of 18° with the horizon, which is nearly the angle of draught in the plough. Hence, in the plough-yoke, the traces being at 18°, the principal condition will be very nearly fulfilled, and there will be no undue tendency either to take from or add to the effect of his natural weight. If he is made to draw at a higher angle, such as would cause the line of draught to fall still beyond the position of his hind-feet, he will feel an unnatural pressure towards the earth on his fore-quarters; and if the angle is still increased till the line fall *within* the position of his hind-feet, the unnatural pressure would extend to both fore and hind quarters; if the contrary, at a lower angle, as at *a b*, the line of draught lying thus above the centre of gravity, the effect will tend to lift the fore-quarters from the earth. Any tendency towards lifting his fore-quarters takes directly from the power of the horse; and any tendency towards pressing upon his fore-quarters, though it will not reduce his power directly, will produce a necessity for greater exertion in his muscular system throughout, by having to move with what is equivalent to an increase of his weight.

503. In the *two-wheeled cart* we can observe a very neat adaptation of the *principle* here brought forward; and though it appears justly adapted to suit the case, it has probably been realised more from chance than from reasoning, but most probably from a long course of observation, without reference to causes and their effects. In the cart with wheels of the height commonly employed, we have the line of draught determined by the radius of the wheel, the height of the hook in the horse-collar from the ground, and the distance from that hook to the centre of the axle. The height of the hook may be taken at 4 feet 6 inches, the radius of the wheel at 2 feet 3 inches, difference 27 inches, and the horizontal distance 7 feet 6 inches, giving an inclination to the line of draught of about 12°, corresponding to the line *a c*, fig. 216. The plane of this line lies higher than the centre of gravity of the horse, and for that reason would have the tendency of taking from his weight; but to obviate this, the necessity arising from the nature of the vehicle, that a small portion of its weight be thrown upon the horse's back, comes aptly in to restore the equilibrium. By throwing a portion of the pressure of the load upon the back of the horse, we do in effect lay an extraneous body upon that part of the animal, which, for the time, becoming in effect a part of his entire mass, raises his centre of gravity, and, if all is properly adjusted, it will be again in the plane of the line of draught, and the fore-quarters of the horse will be nearly as free to move as before. There will, however, be an additional pressure thrown upon his hind-quarters by this extraneous weight; but this is again compensated by the average force of traction in the cart being less than that of the plough, in the proportion of 120 to 160. Although, from the nature of the subject, we cannot reduce these data to any minute calculation, there appears to be sufficient grounds to establish the foregoing remarks, as being based upon the legitimate principles that govern the determination of the angle of draught. It is certainly evident that the nearer we can approach to the principle of coincidence of the centre of gravity of the horse and his load with the plane of the line of draught, so much the nearer are we to removing all unnecessary exertion of the animal.

504. From these considerations, it follows that the angle of draught, so far as regards the horse, should not exceed 18°, but that it may range from that to the horizontal line, or even to ascend above it, provided that duly proportioned extraneous loads be placed upon him. We see here also a corroboration of the advantages of two-wheeled carts over four-wheeled waggons; for if the foregoing views are correct, waggons having four wheels of the same height as common cart-wheels, the shaft-horses in such waggons never can give out their full effect, or an effect equal to what they would do in carts; and it is curious to remark, that giving to waggons high front-wheels, which is now

becoming prevalent, is rendering them less effective than under the old system of low front-wheels, so long retained for the convenience of turning. Waggons with low fore-wheels brought the line of draught to nearly the same angle as in the plough; hence the shaft-horses would give out their maximum effect, and what is more, the higher angle of draught must have served to counteract the disadvantage under which low wheels must always lie in passing over obstacles, or in soft roads producing a continuous obstacle.

505. We see here also the disadvantage of employing two, three, or more ***horses in line***, whether in the plough, the cart, or the waggon, for in all such cases every horse before the one in the shafts must of necessity draw upon a line nearly horizontal; and it is not too much to say, that, so yoked, a horse will not give out more than $\frac{4}{5}$ to $\frac{5}{6}$ of his full working effect. This conclusion agrees with well-established practice under the Scotch system of managing horse-labour; and it is, moreover, seen to be gaining favour over the still older practice of the four-wheeled waggon; for in a report of experiments, on the large scale, of the reduction of horse-labour by the use of single carts, by Mr Hannam of Burcott, Oxfordshire, a saving of expense, on the carting alone, of a farm, amounts to 19 per cent, as compared with team-labour in waggons, and no less than 47 per cent when the pair-horse system is extended to all the operations of the farm.

506. We have thus endeavoured to establish some data for the angle of the line of draught, showing that it is not necessary to be alike in every case, and that beyond a certain limit either way it is disadvantageous to the horse. In the cart, as well as in the plough, it is confined practically within a small range of angle; thus the height from the ground to the centre of the axle gives nearly an invariable point. The hook of the collar is subject to small variation, arising from the height of the horse and the distance between the hook and the axle; and, in some descriptions of carts, is liable to more considerable variation; but, on the whole, the range will be between 8° and 13°; and it is to be kept in view, that the straight line lying between the hook of the collar and the centre of the axle is invariably the true line of draught. It is not affected by any bolstering up of the cart upon the axle, nor by lowering it, though these two conditions have an influence on the load, as they tend to raise or lower its centre of gravity; and to keep that low should be an invariable rule. In yoking the horse in the cart, the back-chain should be so adjusted to length as to place the shoulder-slings or draught-chains in the ***straight line towards the axle;*** every deviation from this places the horse at a disadvantage. If the back-chain is too long, so as to make the draught-chains range towards a point below the axle, the horse will be unnecessarily loaded on the back, causing undue exertion both before and behind; if the contrary, he will be deprived of part of the benefit of his weight, and his fore-quarters will not have their due share of effect on the draught.

507. For horses employed in ***light carriages going at a high speed***, the draught-chains or traces are not required to be at such a high angle as for heavy loads at a low speed, the amount of draught in cases of high speed becoming very small as the speed increases, and the effect of the angle of draught has little influence on the amount of exertion, and in all such cases it is better to approach as much as possible towards the horizontal line.

508. This leads us to consider the ***effect of springs on loaded carriages.*** Of the efficacy of springs in fast carriages there can be but one opinion, whether we regard safety, comfort to man and beast, and ease of draught. For all vehicles also employed for carrying the lighter description of loads, the advantages of springs seem equally well established; but for all such purposes they

should possess the property of admitting undulation in the vertical direction only, with as little horizontal motion as possible. The latter, especially in the direction of the draught, produces constant inequalities in the resistance to the draught, from the swinging motion of the vehicle, whereby the momentum which at any one instant may have been acquired by the carriage, may be destroyed by a swing of the suspended body in an opposite direction. The grass-hopper-spring, in some of its modifications, is the one to be adopted in all such cases. The effect of the grasshopper-spring being to produce vertical motion almost solely, has the beneficial effect of greatly lessening the jolts and shocks that vehicles are subject to on the very best of roads, and in the case of small obstacles being presented to the wheels these springs perform a very important part. Instead of the whole mass of the carriage being instantaneously elevated upon the obstacle, the wheel and the axle, or, it may be, the bed-frame of the carriage, are in the first instant raised, and are allowed to do so by the yielding of the springs before this upward motion is communicated to the suspended part of the vehicle, thus dividing the upward impetus between the two. In descending from any such obstacle, the reverse of this process occurs, the fall being in like manner broken by the elasticity of the springs; but this is not all the advantage, for in thus passing over a stone, or any obstruction that occupies but an instant of time, the yielding of the spring before elevating the load, will, in effect, reduce the height of the obstacle to an extent proportioned to the elasticity of the spring, thereby requiring less exertion of the power to take the carriage over it.

509. The useful application of springs to heavy-loaded carriages has also been frequently recommended by those who may be competent judges; and it must be admitted that they might be applied with beneficial effect, in so far as regards the draught and ease to the animals of draught; but a serious obstacle intervenes, the expense—and especially if the expense incurred would balance any advantage that might accrue from their adoption. The cost of a set of springs for a single-horse cart, supposed to bear a load of 1½ tons, cannot be less at the present time than £3, which adds more than 25 per cent to the price of the cart complete without springs; and we are yet without any certain data by which we can calculate that a horse would take a greater load upon a cart so constructed. There can be no doubt that roads and horses would be benefited by the introduction of springs to all carriages; but it is yet an unsolved problem, whether, on the whole, it presents that amount of economy to make its adoption an object to the farmer.

510. There is one other point yet in connection with the draught which is deserving of notice, and it bears also some relation to springs. We have said that if springs are applied to carriages, they should be so constructed as to afford no elasticity in the longitudinal direction. Such elasticity destroys the impetus that may have been generated in the carriage, in the case of the wheels being checked by any obstacle; and instead of that impetus being directed to the carrying of the vehicle over the obstacle, the sudden shock allows the whole of the momentum to expend itself in causing the suspended body of the carriage to be swung forward, while the whole mass is nearly or altogether brought to rest. This is, without doubt, true, both in theory and practice; but the theoretical part of it has been carried further than this, for we find a clever writer asserting that not only should there be no elasticity longitudinally between the wheels and the carriage, but it should also be entirely banished from between the wheels and the horse.* This is certainly not agree-

* *Library of Useful Knowledge*—"The Horse," p. 445.

able to practice; and, what is more, it is contrary to a well-known principle, that impetus or momentum will enable a body to overcome obstacles, which it could with difficulty accomplish if starting from a state of rest. A horse, therefore, at the first instant of his motion, having not yet acquired any momentum, but moves simply with his initial force, will not have an effect upon the load on a carriage equal to what he would acquire in the succeeding instant, when his initial force has been multiplied by his velocity. We apprehend, therefore, that there ought to be a distinction between that longitudinal elasticity that may exist in a carriage betwixt the wheels and its body if suspended on springs, and that betwixt the wheels and the animal of draught, or the power, whatever it may be. Everyday experience teaches us this fact; for who has not observed that the draught-chains of a horse that have stood all the ordinary strains of dragging the same loaded cart, plough, or machine, for days or weeks, when the horse is allowed to take a step in advance before they have been brought to their bearing, snap asunder; and what can have produced this fracture but some power more intense than the chains have hitherto undergone—the increased momentum of the horse? Such being the case, there must be some advantage in having a degree of elasticity interposed between the shoulders of the horse and the ultimate resistance—the wheels of the carriage. Independent of the occasional advantages afforded to the horse for overcoming obstacles, such an arrangement will yield much ease and comfort to the animal; and fortunately, too, nature has provided the means for this compensation, both in the animal structure and in the physical condition attendant upon inert matter. Thus, in the animal frame, those parts upon which the actions under consideration depend, are more or less yielding and elastic; and again, the substances that form the media through which the force of the animal is applied, both from their inherent nature and the external laws under which they act, necessarily partake of the principle of elasticity. For example, if a chain is employed as a medium, its *gravity* has a perpetual tendency to make it assume the *catenarian* curve, and the change of form, from the curve towards the straight line, produces a beautifully elastic spring. In the plough this is particularly the case, and it exists more or less in every arrangement of strain or draught, from the chain-cable of our floating bulwarks, through the tow-line on the canal, the buffers, connecting-links, and springs of the locomotive, down to the meanest office in which either inert matter or *animals* of draught are employed as a medium of traction. Where a less rigid material than iron is employed, such as hide, leather, hemp, and other substances, though they partake less of the catenarian elasticity, from their lower specific gravity, a compensation is afforded by their inherent elasticity. We may here infer, that where nature has so largely provided a principle which appears to be on all occasions advantageous, and conservative of both living and inert matter, it were folly in us to attempt counteracting it, and much more so when from its abstraction we should earn nothing but disadvantages.

511. The inference to be drawn from the above remarks is, that instead of endeavouring to render the *yoke* of a horse, or all that intervenes between his shoulders and the cart-axle, as rigid as possible, we should, on the contrary, give it elasticity, and by so doing we shall not only render the labour of the horse more endurable, but we prevent innumerable accidents, by breakage, to the substances that are employed as the medium of draught—chains, traces, swing-trees, and the like. The draught of ploughs will be treated of in the section on *Ploughs*, Book Second.

512. In paragraph 477 we alluded to the dynamometer and the friction-brake:

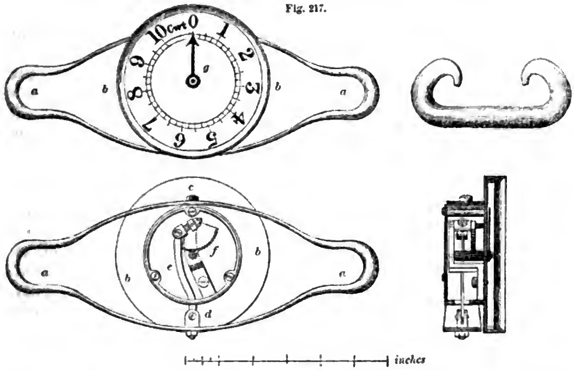
the dynamometer, useful to ascertain the relative strength of animals in dragging instruments, as ploughs, carts; and the friction-brake, to estimate the amount of useful effect lost by friction in machines of revolution, as steam-engines, &c. These apparatus we shall now describe.

513. The simplest form of *dynamometer* for ascertaining the draught of ploughs is the ordinary spring-balance placed within a cylindrical case. The hook which terminates the spring is attached to the whipple or swing-tree, the other hook at the end of the case being attached to the plough-bridle. The movement of a pointer, or the extent to which the spring-lever is pulled out, shows the amount of draught.

514. Another and usual form of spring dynamometer consists of an elliptical spring, to the ends of which hooks can be attached to connect the spring to the plough on the one hand and the whipple-trees on the other, thus making it to form a link in the line of draught of the implement to be tested; the whole of the draught is thus transmitted to the spring, the force exerted upon it altering its form, increasing its length, and causing the sides to collapse in proportion to the strain.

515. In fig. 217 we illustrate a form of dynamometer on this principle, manu-

Fig. 217.



SLIGHT'S DYNAMOMETER.

factured by Messrs Slight, agricultural engineers, Leith Walk, Edinburgh. Within the spring *a a* a circular brass box *b b* is placed, and attached to one side of it by a single screw *c*. The opposite side of the spring carries a stud *d*. To this a light bar or connecting-rod *e* is jointed. This bar is connected with a segmental rack *f*, the teeth of which take into those of a small pinion. This pinion is fixed on a small axle, which carries the pointer *g* mounted in front of the circular dial. This dial indicates a number of cwts. from 0 to 10. The position of the pointer indicates the amount of compression which the spring has sustained by the draught of the acting force and the resistance which it has to overcome, and the force in cwts. which is applied to the draught.

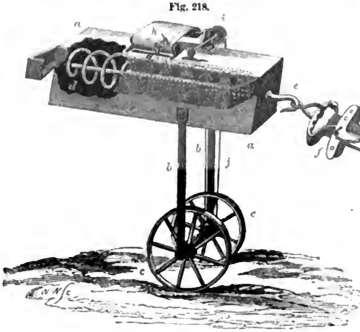
516. Fig. 217 contains first a front elevation of the instrument with its pointer-index; secondly, a back view, with the cover removed, to show the internal arrangement, and the connection *c d* between the sides of the spring

and the segmental rack and pinion *f*; thirdly, a section through the box and spring; and, fourthly, one of the draught-hooks by which the spring is connected with the plough and the moving force. The dial-plate is protected from injury by a glass plate in front. For convenience, the instrument, with the necessary pair of hooks to form the connection between the plough and the horse, are packed in a small box. The price of the whole complete is £3, 15s.

517. In the form of dynamometer now described, the indications of the pointer are read off by the eye, while the implement to which it is attached is at work. This simple form of apparatus, we are inclined to think, indicates results in a sufficiently precise and available way for the majority of practical purposes; but from the inequalities of land through which the plough has to pass during its operation, and from the irregularities in the draught of the horses which work it, considerable variation in the rapidity of motion of the pointer arises: this changing irregularity from slow to quick, and *vice versa*, renders it a difficult matter in some cases to ascertain the points which it indicates. A machine has therefore been desiderated by some authorities which would accurately *register* the movements of its pointer; these being marked off on paper, which, after the trial, would afford data to strike an average of the indications. The most notable of dynamometers of this kind are those of Mr Bentall of Heybridge, Essex, and of M. Morin of France.

518. In fig. 218 we give a perspective sketch of a Danish dynamometer of MM. Gamst and Lund, exhibited at the Paris Exhibition of 1855, and reported on very favourably by the jury. In its compactness and simplicity of construction it contrasts favourably with other self-recording dynamometers which have been introduced from time to time. We are indebted for our illustration and description to the *Journal d'Agriculture Pratique* of February the 20th, 1857. It is constructed on the same principle as Mr Bentall's—a coiled or helical spring being employed, as the drawing, fig. 218, indicates. This spring is enclosed in a box or case *a a*; to this are attached the vertical standards *b b*, carrying the wheels *c c* on which the apparatus runs. In the drawing, part of the case is broken off, in order to show the disposition of the coiled spring *d*. The hook *e* forms the extremity of the central bar, round which is coiled the spring, and to the opposite end of this central bar the extremity of the last spiral of the spring is fixed, and the horses yoked by means of their swing-trees. The hook *e*, riveted to the end of the box *a a*, serves to connect the bridle *f* of the plough—the draught of which has to be tested—to the dynamometer. To the extremity of the axle of the right-hand wheel a small pulley is keyed on, this carrying in its grooved periphery an endless band *j*, which passes over the upper pulley *i*, the periphery of which is similarly grooved. This upper pulley *i* moves, through the medium of a pair of mitre or bevel wheels, a sheet of white paper *h*, which is stretched between, and rolls upon,

Fig. 218.

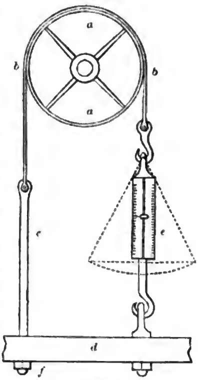


DANISH SELF-REGISTERING DYNAMOMETER.

two cylinders placed parallel to each other. The right-hand wheel, in turning as the machine is dragged over the ground, turns the pulleys, and causes the paper, through the medium of the bevel-wheels and cylinders, to move in a line at right angles to the length of the machine. A pencil *g*, fixed on a bar which is attached to the last spiral of the spring *d*, is placed in contact with the paper; and as it is caused to move to and fro by the irregular action of the draught in a line at right angles to the direction of motion of the sheet of paper, the result of the two motions is a curved or irregular line drawn upon the paper, the undulations of which are proportioned to the tractional efforts of the horse.

519. The dynamometers above described are applicable only to cases where the draught is applied in a direct line. To ascertain the power in prime movers, as steam-engines, or machines of revolution, the friction-brake is used; the object of which is to convert all the work performed by the machine into friction, and then to measure that friction. A very simple form of friction-brake is illustrated in fig. 219, where *a a* is a pulley keyed on the main shaft of the engine or machine. The periphery of this must be turned perfectly smooth and true. An iron hoop *b b* is placed over the pulley, one end of which is fastened to the bar *c*, passing through the block *d*; this bar can be lowered by the nut *f* acting on its screwed extremity. The other end of the hoop is fastened by its hook to the ring of the spring-balance *e*, firmly connected to the block *d*. The hoop *b* is brought in close contact with the pulley by tightening the nut *f*, and the machine is made to work at its usual speed. By this arrangement the power is absorbed by the friction between the pulley and hoop, which in time checks the machine. The hoop acts on the spring, pulling out the bar and indicating a certain weight, which represents the resistance to the working of the machine. If we multiply the weight in pounds thus indicated, by the circumferential velocity of the pulley *b b*, dividing the quotient by 33,000, the amount of labour in horse power performed by the machine at the time of registration is obtained. This brake gives only approximative results, but is sufficiently useful for ordinary purposes. Weights may be placed in a dish—as shown by the dotted lines—as a substitute for the spring-balance.

Fig. 219.



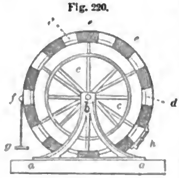
FRICTION-BRAKE.

520. A more perfect kind of friction-brake is that known as Prony's, which acts on the principle of the lever. A pulley is provided, cast in two halves; these are made to embrace the shaft of the engine or machine to be tested, and are united by bolts and nuts. Two iron jaws embrace the periphery of the pulley, and are tightened down by screws. The lower jaw is lengthened to form a lever; at the extremity of this lever a dish containing weights is suspended. In using this apparatus to test the power of a machine, weights corresponding to this power are put into the scale; these weights, acting through the medium of the lever, producing a pressure equal to the power. The weight of the lever, from its extremity to the centre of the pulley on the shaft, including the weight of the dish in which the weights are to be suspended, must be ascertained. Having fixed the apparatus, and put weights into the dish so as to bring down the lever to some distance below the horizontal line, the machine is started with a gradually increasing velocity. When the machine is going at its proper

rate, and the lever raised a little above the horizontal line, or rather balanced properly, the weight represents the amount of its power. Should the lever be raised too much above the balance-level, more weight should be added to the dish: should, on the contrary, the lever fall below the balance-level, the machine is short of the power required to raise it, and some of the weight must be taken out of the dish. The weight which is thus found to balance the ordinary working power of the machine enters into the calculation for ascertaining its power of working effect. The following is the rule, premising that, before using the brake, the apparatus is arranged so as to balance when suspended on its centre of gravity; this balancing will obviate the necessity of making the weight of the lever and its accompanying dish enter into the calculation of the circle: "Multiply the circumference described by the end of the lever by the number of revolutions of the shaft per minute, and by the weight in the scale, and divide the product by 33,000, and the quotient will be the actual force of the machine in horse-power."

521. In fig. 220 we illustrate the form of dynamometer used at the trial of the steam-engines at the Royal Agricultural Society of England's meetings: *a a* the base, *b* the upright or pedestal which supports the shaft of the pulley *c c*, with which the driving-belt of the engine to be tested is placed. On the same shaft a large friction-wheel *d d* is keyed, provided with a strap and friction-blocks *e e*; the rod *f* carries a dish *g*, in which the weights are placed to test the power; the strap and blocks are tightened up by the screw *h*. For the mode of ascertaining the results, and of using the data thus obtained, see the section on *Steam-Engines*, Book Second. We are indebted for this illustration to Mr Waller's paper, there alluded to.

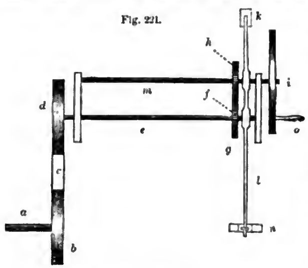
Fig. 220.



DYNAMOMETER FOR TESTING POWER OF STEAM-ENGINES.

522. The dynamometer invented by Mr Amos, Consulting Engineer to the Royal Agricultural Society of England, possesses many ingenious arrangements. It has been instrumental in detecting many defects in the working of our farm machines. It indicates with remarkable precision the force exerted by a machine in the performance of a given amount of work, and also registers the number of revolutions it makes during the time it is at work. Fig. 221 will illustrate the principle on which this dynamometer operates. Let *a* represent the shaft of the machine — as a chaff-cutter — the force required to work which, it is desirous to estimate. To the extremity of this shaft a pulley or arm *b* is keyed; the band or belt *c* of this is made to pass over the pulley *d* of the dynamometer, which is brought close up to the machine to be tested. The end *f* of the shaft *e* on which the pulley *d* is keyed is passed into an oblong slot or mortise, forming part of a lever *l*. This slot is of such dimensions as to allow the end *f* of the shaft *e* to have a certain amount of traverse or play in a vertical direction. The lever *l* has its centre of vibration in the shaft *m*, and is continued backward, and terminated by a weight *k*. The

Fig. 221.



AMOS'S DYNAMOMETER

weight *k* is so adjusted that when the machine is at rest the lever *l* and the wheel *g* are balanced so that the end of the shaft *e* rests unsupported in, or is balanced in, the slot in the lever *l*. Near the end of the shaft *m* a spur-wheel *h* is keyed, the teeth of which take into those of the spur-wheel *g* of the same size and pitch, keyed on to the shaft *e*. To the extremity of the shaft *m* a fly-wheel *i* is fixed, provided with a handle *o*, by which it is turned, the radius of the leverage *i o* being equal to the radius of the pulley *d*, or of *b*. By this arrangement the force required to turn the pulley *b* of the machine under trial is transferred to or must be overcome by a force applied to the lever *o* of the wheel *i o*, this force being measured as follows: After the connection is made between the machine to be tested and the dynamometer by the band *c*, the power is applied to the handle *o*: the tendency of the resistance of the machine under trial is to prevent the wheel *g* from revolving, and to cause the power of the wheel *i*, acting through the wheel *h*, to lift *g* up, raising its shaft in the slot of the lever; and lifting the extremity *n* of the lever *l*. As the power is continued to be applied to the handle *o*, weights are suspended at *n* until the two wheels *h* and *g* begin to revolve, the weights at the same time pressing the end *f* of the shaft *e* down in the mortise or slot of the lever *l*. The weights thus obtained, therefore, at the extremity of the lever *l*, multiplied by the power they exert on the lever, is the measure of the force required to overcome the resistance of the machine under trial. The number of revolutions which the machine makes during a given time is registered by a pendulum acting on a counter attached to the framing of the dynamometer.

BOOK SECOND.—PRACTICE.

ON THE PRACTICAL CONSTRUCTION, PROPERTIES, AND USES OF FARM IMPLEMENTS AND MACHINES.

523. Before engaging in the practical department of our work, it is proper to make the reader acquainted with the general arrangement of the subjects which we have adopted, and which arrangement must partake in a great measure of an arbitrary character, as also with the various subjects to each of which we shall have to direct his special attention.

524. On taking an extended survey of all the implements and machines of the farm that have ever existed, they may be viewed under these three aspects: *first*, Those which have been used, and have become obsolete; *secondly*, Those which exist, but are not used; and, *thirdly*, Those which exist, and are used.

525. It were obviously a self-imposition of a useless task to trouble ourselves with a description of implements and machines which for a time had been used, but had been abandoned, on account of their own unworthiness, as soon as better had appeared. It would be equally futile to notice those which may once have attracted considerable attention by the novelty of their construction or great pretensions, but are now seldom used or even heard of, although they may still be found in the implemental store of some farmsteads. During the last fifteen or twenty years both these descriptions of implements and machines have been presented to the notice of the farmer in great profusion, and have induced him to expend large sums on their purchase. There remain only those implements and machines in actual use to demand our attention, and upon which we shall now bestow our regards in the second department of our work.

526. While thus our review of the implements and machines of the farm must be restricted to those actually in use, the best mode of treating each of them demands our most serious consideration. Must every one in use be figured and described? If that were so, their description would occupy so bulky a volume as to become repulsive to every one who desired to purchase it. But a voluminous description is not necessary. Some classes of machines—as the turnip-sowing machines, for example—are so multifarious in construction, and unnecessarily so, that the repetition of their description would become inevitably tiresome. Nor is it to be proposed that every implement and machine in use is to pass in review before the reader, as if under a critical examination of its construction; for beside the arrogance of such a proceeding, it would be very unfair to implement-makers to institute what could not but be deemed an invidious comparison betwixt their respective manufactures. Enough for us

to accomplish, if we accomplish it well, is the indication of those machines of each class which combine in their construction the principles which have been enunciated in the former part of this work, with that mechanical skill which evinces an intimate knowledge of the strength and properties of the materials employed, so that the use of such machines may produce the largest amount of good work with the least expenditure of power.

527. To accomplish even this restricted task with the degree of explicitness required, will necessarily occupy a considerable space; and we believe, moreover, that such a task should only be undertaken by a combination of mind, and not by any single individual; for a knowledge of general mechanical principles, a facility of mechanical representation, an aptitude of mechanical description, and a practical experience of the use of implements and machines at work, are all requisite in order to place even the simplest of them in a vivid picture before the reader.

528. Numerous as are the implements and machines brought into operation by the requirements of modern husbandry, and varying greatly as they do in their characteristics of arrangement and construction, they may nevertheless be classed under two great divisions—1. Implements and machines connected with the cultivation of the soil; and, 2. Implements and machines connected with the products of the soil; and these divisions may be subdivided into as many sections as there are various classes of implements and machines suited to the different operations of the farm, conducted in each of the seasons of the year. To those two great divisions others may be added, so as to comprise all the mechanism which aids the farmer in carrying out his important avocations, and which are the moving powers of the farm, and the convenient arrangement of the machines in the steading.

529. The arrangement of the subjects will therefore be as follows :—

530. DIVISION FIRST.—IMPLEMENTS AND MACHINES CONNECTED WITH THE CULTIVATION OF THE SOIL.

531. *Section First.*—Ploughs, including steam-ploughs, trench and subsoil ploughs.

532. *Section Second.*—Grubbers, scarifiers, cultivators.

533. *Section Third.*—Harrows, clod-crushers, weed-extirpators, rollers.

534. *Section Fourth.*—Horse-hoes, scufflers.

535. *Section Fifth.*—Sowing-drills, manure-distributors.

536. *Section Sixth.*—Manual implements connected with the above sections, as draining tools, &c.

537. DIVISION SECOND.—IMPLEMENTS AND MACHINES CONNECTED WITH THE PRODUCTS OF THE SOIL.

538. *Section First.*—Haymaking machines.

539. *Section Second.*—Corn-reaping machines.

540. *Section Third.*—Barn machines, including thrashing-machines, fixed and portable; winnowing-machines, hummellers, corn-cleaning machines, corn-weighing machines.

541. *Section Fourth.*—Carts, waggons.

542. *Section Fifth.*—Chaff-cutters, hay-knives.

543. *Section Sixth.*—Turnip-slicers, root-pulpers.

544. *Section Seventh.*—Corn-bruisers, corn-mill, linseed-mill, oilcake-breaker.

545. *Section Eighth.*—Boiling and steaming apparatus.

546. *Section Ninth.*—Dairy machines, cheese-presses.

547. *Section Tenth.*—Manual implements connected with the above sections, as forks, graips, shovels, barn implements, dairy utensils.

548. *Section Eleventh.*—Machines not directly connected with any of the above sections, but useful on the farm.
549. DIVISION THIRD.—MOVING POWERS OF THE FARM.
550. *Section First.*—Horse-power, horse-wheel.
551. *Section Second.*—Water-power, water-wheels, turbines.
552. *Section Third.*—Steam-power; steam-engines, fixed and locomotive.
553. *Section Fourth.*—Wind-power.
554. DIVISION FOURTH.—ARRANGEMENT OF MACHINES IN THE STEADING.
555. *Section First.*—Arrangement of machines in the ground-floor.
556. *Section Second.*—Arrangement of machines in the upper floor.
557. *Section Third.*—Arrangement of small machines with the moving power.

DIVISION FIRST.—IMPLEMENTS AND MACHINES CONNECTED WITH THE CULTIVATION OF THE SOIL.

558. SECTION FIRST—*The Plough.*—The present age is perhaps the most remarkable that time has produced, for the perfection of almost every kind of machine or tool required in the various departments of art and of manufactures. In that most important of all arts — the production of the raw material of human food—something like a corresponding progress has been effected in its machinery and tools, though certainly not to the same degree of perfection as those employed in most of our manufactures, whether they be from the animal, vegetable, metallic, or mineral productions. Various causes exist to prevent, or at least retard, an equal degree of perfection being arrived at in agricultural machinery, amongst which may be noticed one pervading circumstance, that affects more or less almost every machine or implement employed. This circumstance is, that all the important operations of the farm are performed in *seasons* occupying comparatively short periods of time; and should the artisan be endeavouring to produce any new or important machine, he can only make trial of it in the proper season. The imperfection of human perception is too well known to leave us in surprise at the first attempt of any improvement turning out more or less a failure. The artisan, therefore, will in all probability find that his project requires amendment; and before that can be effected, the season is past in which a second trial could be made; and, consequently, it must be postponed for a year, in the course of which many circumstances may occur to cause its being forgotten or abandoned. Impediments of this kind do not occur to the inventor or improver of manufacturing machinery, where constant daily opportunities occur to test the successive steps of his invention.

559. One other general cause, and of another kind, exists, to supersede the necessity, or even the propriety, of employing machinery of such high and delicate finish as we see in the machines of all in-door manufactures: this is, the irregularity of the media on which agricultural machinery is employed, and the numerous changes produced on these media—the soils and produce—by vicissitudes of weather and other causes, which not only affect the operation, but also the existence of many of these machines. From this cause, with its train of incidents, it may be inferred that agricultural machinery and tools must of necessity be of simple construction, which shall embrace nothing but the essentials of usefulness; that they have sufficient strength for their intended purpose, and free of any undue weight; that there should be no redun-

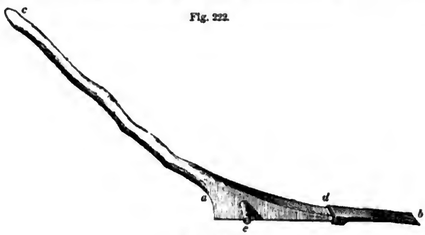
dancy nor misapplication of materials; that all materials employed should be of the best quality, and the workmanship plain and sound—which properties, it must be admitted, are of greater importance to agricultural machinery in general, than the minute delicacy of construction and finish observable in many of those almost intellectual tools employed in some of the other arts and manufactures.

560. Although, therefore, agricultural machines in general do not require a high mechanical finish, yet there are amongst them those which are based on principles implying a knowledge and application of science, as well as mechanical skill in their construction; and in this class is to be ranked the *Plough*, which, in one word, is as yet the most important of all agricultural machines.

561. To the *plough*, then, our attention is first to be directed, not only as standing at the head of all its fellows in the ranks of the machinery of the farm, but as being the first implement to which the attention of the farmer is called, in the commencement of his agricultural year—the Winter season.

562. Before entering upon the details of the implement as it now appears, it may be interesting to take a short retrospective view of its history. With the earliest stages of human industry, the tillage of the ground in some shape must be considered as coeval; and in those early attempts, some implement analogous to a plough must have been resorted to. In all ancient figures and descriptions of that implement, its extreme simplicity is to be remarked; and this is but a natural result; but with the progress of human intellect is to be also observed deviations from the original simplicity, and an increase in the number of its parts, with a corresponding complexity in its structure. The Roman ploughs, imperfectly as they are described by different Roman authors, are an example of this. And as an example of apparently very remote origin, the *caschrom*, or plough, used even at this day in some parts of the Outer Hebrides and Isle of of Skye, in Scotland, forms a very curious and interesting antiquarian relic of the ancient Celtic habits. It is formed, as in fig. 222, of one piece of wood, selected from its possessing the natural bend at *a*, that admits of the head *a b* assuming a nearly horizontal position, when the handle *c* is laid upon the shoulder of the person who wields the implement. A simple wedge-shaped share *b d* is fitted to the fore part of the sole. A wooden peg *e* is inserted in the side of the heel, which completes the implement. On this last member the foot of the operator is applied, to push the instrument into the ground. It is of course worked by the hand alone, and makes simply a rut in the ground. Yet even in this rude implement are to be traced the rudiments of the plough.

Fig. 222.



THE CASCHROM.

563. As the cultivation of the soil became more and more an object of industry, corresponding improvements naturally followed in the implements by which such operations were performed. But in Britain, previous to the beginning of the last century, the plough appears to have continued in a very uncouth state. About that period, agriculture seems to have become more an object of

improvement. Draining began to be studied, and its effects appreciated. The amelioration of the soil produced by draining would soon call for better modes of dressing such improved soils; hence still further improvements in the plough would come into request. In accordance with this, we find the introduction of an improved plough into the northern counties of England under the name of the Dutch, or Rotherham plough. This appears to be the foundation of all the modern improvements, and from the circumstance of engineers and mechanics having been brought from Holland to conduct the draining of the English fens, there is good reason to conclude that the Rotherham plough was originally an importation from Holland, in a similar manner as the barley-mill was, at a later period, borrowed from that country. About the middle of the past century, the Rotherham plough appears to have been partially introduced into Scotland; but until James Small took up the subject, and, by his judicious improvements, gave a decided character to the plough, little or no progress had been made with it.

564. Small appears to have been the first who gave to the mould-board and the share a *form* that could be partially imitated by others, whereby, following his instructions, mould-boards might be multiplied, each possessing the particular form which he had directed to be given to them. It is to be observed, that when Small first taught the method of construction, mould-boards were really *boards* of wood, and, for their defence, were covered with plates of iron. The method of construction being not very clearly defined, and mould-boards being necessarily constructed by many different hands, the improved plan, it may be easily conceived, must have been liable to failure in practice. It was therefore one of those happy coincidences which now and then occur for the benefit of mankind, that the founding of cast-iron was then beginning to become general. The fortunate circumstance was seized. Mould-boards, together with the head or sheath, and the sole and land-side plates, were made of cast-iron; and a model or pattern of these parts having been once formed, any number of duplicates could be obtained, each possessing every quality, in point of form, as perfectly as the original model. The plough, thus in a great measure placed beyond the power of uninformed mechanics to maltreat, came rapidly and deservedly into public esteem, under the name of Small's plough. Though originally produced in Berwickshire, the plough that seems to retain the principal feature of Small's improvements—the mould-board—is now found chiefly in East-Lothian, and differs very sensibly from that now generally used in Berwickshire.

565. Other writers, about the same period, published methods for constructing a mould-board on just principles. Amongst these, the method proposed by Bailey of Chillingham may be mentioned as approaching very near to the true theoretical form. Others less perfect have been proposed, which it is not necessary to notice; while several have published general descriptions of their construction of the plough, but have withheld the principles upon which their mould-boards are formed.

566. While these improvements of the past century were going on, the plough was universally constructed with *wooden framing;* but about the beginning of the present century (the precise year cannot now be well defined), malleable iron began to be employed in their fabrication. The application of this material in the construction of ploughs came with so much propriety, that it is now, in Scotland, almost universal. It has many advantages; but the most prominent are its great durability under any exposure, and its better adaptation to withstand the shocks to which the implement is frequently liable in the course of

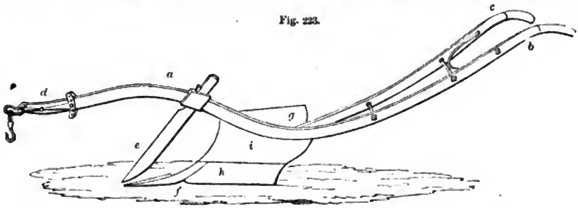
working. In a national point of view, it is also deserving of the most extended application, being from a produce—iron—for which Britain stands unrivalled.

567. This period also was productive of an innovation on the form of mould-board and share which had been established by Small. The mould-boards hitherto referred to came under the denomination of concave, or, more properly, straight-lined; when Wilkie, of Uddingstone, near Glasgow, introduced his new form with convex lines, and which has been adopted in various districts in Scotland, to the exclusion of the concave form.

568. These two forms—the *concave* and *convex*—have undergone numerous slight changes, forming sub-varieties, but retaining the respective leading features of the concave and convex mould-boards; and as they have each spread (especially the first) over a wide extent of country, they may be distinguished by the county in which they are chiefly employed. Thus, the Small's plough is used in East-Lothian, and Wilkie's in Lanarkshire.

569. Before entering upon the detailed description, it will be useful to the reader to give the nomenclature employed in this work of the various parts of the plough, that there may be no misunderstanding of the descriptions which are to follow. Thus, fig. 223, which is a view of a plough in perspective, presents

Fig. 223.



A VIEW OF THE LAND-SIDE OF A PLOUGH.

that which ploughmen and agricultural mechanics denominate the *land-side*—so called, because when in work it is always (except in the case of turn-wrest or right-and-left ploughs) in contact with the firm or unploughed land. The opposite, or right side of the plough, being that which turns over the furrow-slice cut from the firm land, is called the *furrow-side*. That member of the plough to which the animals of draught are yoked, marked *a* in the figure, is the *beam*. Those parts by which the ploughman holds and guides the implement are called the *stilts* or *handles*, *b* being the *great stilt* or *left handle*, and *c* the *little stilt* or *right handle; d* is the *muzzle* or *bridle* by which the horses are attached to the beam; *e*, the *coulter*, is a cutting instrument that severs the slice from the firm land, and *f* the *sock* or *share* which cuts the slice below from the subsoil; *g* is called the *wrest* or *mould-board*. It is probable that the term wrest applied formerly to only a particular portion of the mould-board—the lower portion in the more ancient plough—which was supposed to wrest or turn aside the slice after being cut by the share; thus we find in the Kent turn-wrest plough that the wrest is a simple straight bar of wood. The mould-board, in the improved implement, receives the slice from the share, turns it gradually over, and deposits it continuously at the proper angle: *h* is the *sole-shoe* on which the plough has its principal support, and on which it moves, and *i* is the *land-side plate*, only serving to complete the sheathing of the land-side, presenting a uniform smooth surface to the firm land, and preventing the crumbled earth from falling within the body of the plough.

These last parts cover the body-frame from view, which will be exhibited amongst the details.

570. *The East-Lothian Plough*, figs. 1 and 2, Plate I.—In this plough the proper lines of the body on the land-side lie all in one plane, which, in working, should be held in the vertical position, or very slightly inclining to the left. The coulter slightly oblique to the land-side plane, the point standing towards the left, the rake of the coulter varies from 55° to 65°. In the mould-board the vertical sectional lines approximate to straight lines, giving the character of apparent concavity, and it is truncated forward. Share pointed, with a feather or cutter standing to the right, having a breadth of at least ⅝ the breadth of the furrow, the cutting edge of the feather lying nearly as low as the plane of the sole. The neck of the share is prolonged backward, joining and coinciding with the curve of the mould-board, which curvature is also carried forward on the back of the feather. The character of this plough is to take a furrow of 10 inches in breadth by 7 inches in depth, cut rectangular, leaving the sole of the open furrow level and clean. The resistance to the draught is generally below the average of ploughs, and this plough is employed for every kind of soil.

571. *Lanarkshire Plough*.—The character of this plough is to take a furrow whose section is a trapezoid, its breadth from 7½ to 9 inches, and greatest depth 6½ inches, the sole of the furrow being not level, and deepest at the land-side. In the finished ploughing, the laid-up furrow-slices have the acute angle upward, giving the character which may be called *high-crested* to the furrow-slice, especially observable in ploughing lea. Resistance to the draught about the average, and it is considered to be well adapted to stiff clay, and to lea-land.

572. Before entering upon the *specific details* of the two varieties into which the modern Scotch ploughs are here divided, it will be necessary to *lay down certain data, on which the details of each variety will be based.* For this purpose the figure in elevation, fig. 1, Plate I., is supposed to stand upon a level plane, the heel and point of the share touching that plane, they being actually the points on which the plough is supported when in motion, and which plane is called the *base line*. The fore-part of the land-side of the plough's body—standing in the vertical position, as seen in plan in fig 2, Plate I.—is supposed to be placed upon a similar line, touching the land-side of the sole-shoe and the point of the share. The base-line is divided into a scale of feet for the convenience of comparison. The *zero* of the scale is taken at that part of the plough's body, where a vertical transverse section, at right angles to the plane of the land-side, will fall upon a point on the surface of the mould-board, which shall be distant from the land-side plane by a space equal to the greatest breadth of the furrow taken by the respective ploughs; the height of this point above the base line being also equal to the breadth of the slice. Or, the zero is that vertical section of the mould-board, which, in its progress under the slice, will just place the latter in the vertical position. The *scale*, by this arrangement, counts right and left of the zero. The dotted line marked *surface-line* in fig. 1, Plate I., represents the depth of the furrow taken by the respective ploughs.

573. This zero point has not been fixed on without much consideration; for, having experienced the inconvenience of vague generalities in stating the dimensions of the plough, as given in works on the subject, it has appeared to us desirable that some fixed point should be adopted, and this has been chosen as less liable to change than any other point in the longitude of the plough; all

other points of this implement being liable to and may be changed at pleasure, without change of effect. Thus the beam or the handles may be lengthened or shortened, the position of the coulter and the length of the sole may be varied, the mould-board itself may be lengthened or shortened forward without producing any decided change in the working character of the plough, the apparent changes being easily counteracted by a corresponding change in a different direction. The lengthening of the beam, for example, would only require a corresponding change in the height of its extremity above the base line; an alteration in the length of the share, or in the position of the coulter-box, induces only a corresponding change in the angle which the coulter forms with the base line, which angle, in any case, is liable to change from the wearing of the irons themselves, but which can be rectified as required by shifting the draught-bolt in the bridle. The zero point here proposed can, with tolerable exactness, be determined in any plough with the instruments that every mechanic has in his hands, *squares* and a *foot-rule*.

574. It may be well, also, to premise further, in regard to the contour in elevation of the different ploughs, that although the heights at the different points throughout the beam and handles are given in detail, as adopted by the best makers, which those unacquainted with the implements may follow with confidence, in the construction of implements of the same character, yet we cannot pass over the circumstance without noticing, that, with the exception of one point—the height of the beam at the draught-bolt—any part of the contour may be altered to the taste of the maker, and even the point of the beam, as already noticed, may be altered, provided the alteration is continued backward or forward in a certain angle. The change in position in the vertical direction of three other points is limited within a certain range, not from principle, however, but for convenience. These points are the *height of the beam at the coulter-box* and *at the breast-line* of the mould-board; these cannot be brought *lower* than the given dimensions without subjecting the plough to an unnecessary tendency, to choke in foul ground, though they may be raised *higher* without injury, provided the corresponding parts—the mould-board and body-frame—are altered in proportion. The third point here alluded to is the *height of the handles*, which is altogether a point of convenience; but it may be affirmed of this, that it is better to be *low* than *high*, since being low places the plough more under the command of the ploughman. The different points, as given in the plan, being more matters of principle, with the exception of the position of the handles, cannot be deviated from without compromising the character of the plough.

575. *Details of the East-Lothian Plough.*—Fig. 1, Plate I., represents an elevation of this plough, on the furrow side, drawn to a scale of 1 inch to 1 foot, and fig. 2 a horizontal plan of the same. The letters of reference apply alike to both elevation and plan. The plough is found with various shades of difference, but not to the extent or of such a marked character as to require separate description from what follows. The beam and handles or stilts are almost invariably made of malleable iron, the body-frame being of cast-iron, the latter varying slightly with different makers. In its construction the beam and left handle are usually finished in one continued bar ABC, possessing the varied curvature exhibited in fig. 1, as viewed in elevation. When viewed in plan, as in fig. 2, the *axis* or central line of the beam and *left handle* are in a straight line—though in this arrangement there are some slight deviations among the different makers—the point of the beam being in some cases turned more or less to the right or furrow side, and this is found to vary from ½ inch to 2 inches from the plane of the land-side.

576. The *right handle*, DE, is formed in a separate bar, and is attached to the body-frame at its fore end by a bolt, as will be shown in detail, and further connected to the left handle by the bolts FFF, and the stays GG.

577. The *coulter* I is fixed in its box K by means of iron wedges, holding it in the proper position. Its office being that of a cutting instrument, it is constructed with a sharp edge, and is set at an angle of from 55° to 65° with the base-line.

578. The *mould-board* L, which is fixed upon the body-frame, and to the right handle, is a curved plate of cast-iron, adapted for turning over the furrow-slice. Its fore-edge or breast MN coincides with the land-side of the plough's body; its lower edge T behind stands from 9½ inches to 10 inches distant from the plane of the land-side, while its upper edge P spreads out to a distance of 19 inches from B, the land-side plane. In this plough the mould-board is truncated in the fore part, and is met by the gorge or neck of the share, the junction being at the line N.

579. The *share* or *sock* NR is fitted upon a prolongation of the sole-bar of the body-frame, termed the head, and falls into the curves of the mould-board, of which its surface forms a continuation.

580. The *bridle* C, or *muzzle*, as sometimes named, is that part to which the draught is applied, and is attached to the point of the beam by two bolts, the one S being permanent, upon which the bridle turns vertically. The other bolt U is movable, for the purpose of varying the *earthing* of the plough; the *landing* being varied by shifting the draught-bolt and shackle V to right or left. The right and left handles are furnished at A and D with wooden helves fitted into the sockets of the handles.

581. The *general dimensions* of the plough may be stated thus, as measured on the base-line. From the zero-point O, fig. 1, to the extremity of the heel T, the distance is 4 inches, and from O forward to the point of the share R the distance is 32 inches, giving as the entire length of the sole 3 feet. Again, from O backward to the extremity of the handles A is 6 feet 2 inches, and forward to the draught-bolt V 4 feet 7 inches, making the entire length of the plough on the base-line 10 feet 9 inches; but, following the sinuosities of the beam and handle, the entire length from A to C is about 11 feet 3 inches.

582. In reference to the *body* of the plough, the centre of the coulter-box K is 14½ inches, and the top of the breast-curve M 9 inches before the zero-point, both as measured on the base-line; but following the rise of the beam, the distance from M to the middle of the coulter-box will be 7 inches.

583. The *heights* at the different points above the base-line are marked on the figure in elevation, along the upper edge of the beam and handle; but the chief points in height are repeated here, the whole of them being measured from the base-line to the upper edge of the beam and handles at the respective points. At the left handle A the height is 3 feet, at the right handle D 2 feet 9 inches; and a like difference in height of the two is preserved till the right handle approaches the body at the middle stretcher F; from thence the difference increases till it reaches the body. The height at the point of the beam is 18 inches, and the centre of the draught-bolt V, at a medium, 17 inches. The lower edge of the mould-board behind, of this plough, at T is usually set about ½ inch above the base-line, and at the junction with the share about the same height.

584. The dimensions in *breadth*, from the land-side line, embrace the obliquity that is given to the direction of the beam and handles, compared with the land-side plane of the body taken at the sole. The amount of obliquity, as exhibited by the dotted line AC, fig. 2, which coincides with the land-side plane

of the body, is, that the axis of the beam at the extremity C stands 1¼ inches to the right, and at the opposite end the left handle A stands about 2 inches to the left of the line. These points may, however, be varied slightly from the dimensions here given. In the point of the beam, the variation is found, in the practice of different makers, to range from 1 to 2 inches. In the opinion of some writers and practical men, it is held that the beam should be parallel with the land-side plane of the body. With all deference to such opinions, we apprehend that the direction of the line of draught, in a vertical plane, cannot coincide with the plane of the land-side; for the point of resistance in the plough's body cannot fall in that plane, but will pass through some point to the right of it, and which, from the nature of the subject, cannot be very precisely defined. Both reason and experience, however, point this out to the plough-maker, and especially to the observant ploughman. Hence, also, may be remarked, from the instructions laid down by Small* for the formation of the beam, which, in his time, was made of wood, that the land-side of the beam should lie in the plane of the land-side of the body, and as he directed the beam to be 2¼ inches in breadth at that point, its axis must have been 1⅛ inches to the right of the land-side plane; and in all cases, it must be admitted that the resultant of the effect will lie in the axis of the point, provided the draught-bolt is placed in that line. But, for very sufficient practical reasons, the draught-bolt has a range from right to left, by which the effects of variation of soil and other causes can be rectified at pleasure.

585. A similar difference of opinion has prevailed in regard to the position of the handles, in reference to the land-side plane. In the plough now under review, the left handle deviates only 2 inches from the line, whereas another variety has the handle 7 inches to the left of the line; and this deviation has been advocated on the principle of allowing the ploughman to walk right in the middle between the handles, his right and left arms being equally extended.† Now we would again submit, whether the man who walks with his arms equally extended, and his body equally distant from either handle, or he who is compelled to have one handle always near his body, whereby he can, on any emergency, bring his body instantaneously in contact with the hand, or that which it grasps,—which of these men will have the greatest command over the instrument he guides? Little consideration, we imagine, will be necessary to satisfy the inquirer that the latter will have the advantage.

586. The dimensions of the parts of the *framework* of the plough are: The beam, at its junction with the mould-board at M, is from 2½ to 2¾ inches in depth, by 1 inch in breadth, the same strength being preserved onward to the coulter-box K. From the last point a diminution in breadth and depth begins, which is carried on to the extremity C, where the beam has a depth of 1¾ inch, and a breadth of ½ to ⅝ inch.

587. The *coulter-box* is formed by piercing an oblong mortise through the bar, which has been previously forged with a protuberance at this place, on each side and on the upper edge; the mortise is 2½ by ¾ inches, and the depth 3½ inches.

588. From the junction with the mould-board at M backward, the beam decreases gradually till, at the hind palm of the body at B, it is 2 inches in depth and ⅝ inch in breadth, where it merges in the left handle A. This last member retains a nearly uniform size throughout of 2 inches by ⅝ inch. The right handle D is somewhat lighter, being usually 1½ inches by ⅝ inch, and both terminate in welded sockets, which receive wooden helves, of 6 or 8 inches in

* SMALL's *Treatise on Ploughs.*

† WILKIE in *Farmer's Magazine*, vol. xii. p. 342.

length. The stretchers FFF, which support and retain the handles at their due distance apart, are in length suited to their positions in the handles, and their thickness is about $\frac{3}{4}$ inch diameter, tapering towards the ends, where they terminate in a collar and tail-bolt, with screwed nut. The upper stretcher has also a semicircular stay riveted to its middle, the tails of the stays GG terminating like the stretcher with screwed tails and nuts.

589. Having given the general dimensions and outline description of this plough, there remains to be described the *details of the body-frame and its sheathing, all the figures* of which are on a *scale* of $1\frac{1}{2}$ inches to 1 foot.

590. *The Body-frame.*—The different views of the body-frame are exhibited in the annexed cuts, figs. 224 and 225, wherein the same letters refer to the

Fig. 224.

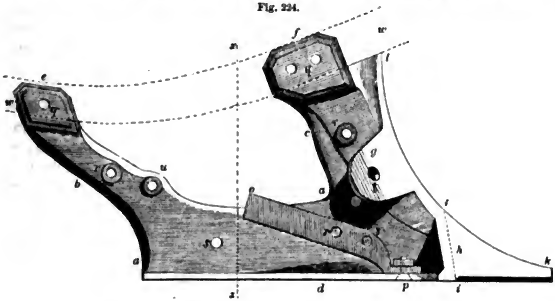
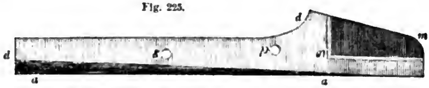


Fig. 225.



THE DETAILS OF THE BODY-FRAME OF THE EAST-LOTHIAN PLOUGH.

corresponding parts in the different figures. Fig. 224 is an elevation of the furrow side; fig. 225, a plan of the sole-bar of the frame inverted; and a vertical section, on the line x x, is given in fig. 226. In all the figures, then, a a is the sole-bar, with two arms b c extending upward, and having at the lower edge a flange d running along the right-hand side. Each of the arms b c terminates in a palm e, f, by which it is bolted to the beam. The arm c is furnished, besides, with an oblique palm or ear g, upon which the fore edge of the mould-board rests, and to which it is bolted. The sole-bar a, with its flange, terminates forward in the head h, which is here made to form the commencement of the twist of the mould-board, and upon which the share is fitted, reaching to the dotted line i i, fig. 224. The fore edge k i l of the frame is worked into the curve answering to the oblique section of the fore edge or breast of the mould-board, and serves as a support to the latter throughout their junction. The curvature given to the arm b is unimportant to the action of the plough, but the general oblique direction here given to it is well adapted to withstand the thrust constantly exerted in that direction when the plough is at work. In fig 225, the

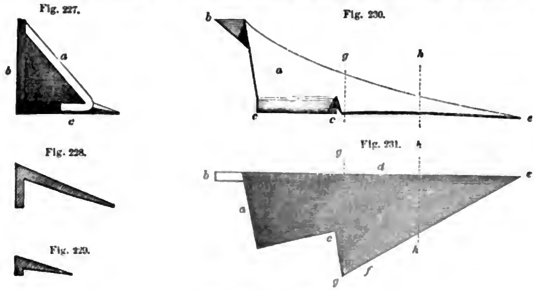
Fig. 226.

A VERTICAL SECTION OF THE FRAME.

sloping edge *d m* represents the enlargement of the sole-bar, on which the share is fitted, and where the lower part of the fore edge of the mould-board rests. The depressed portion *m n* is that which is embraced by the flange of the share. In the frame, fig. 224, *o* is the lower extremity of the right handle, broken off at *o*, to show the manner in which it is joined to the sole-flange of the frame by the bolt *p*. The bolt-holes *q, q* are those by which the beam is secured to the palms of the frame; *r, r* are those by which the land-side plate is attached; and *s, s* those of the sole-shoe, *t* being that which secures the mould-board to the ear, and *u* that which receives the lower stretcher of the handles. (See fig. 2, Plate I., at F and O.) The letter *v* marks the second bolt-hole of the mould-board, while its third fixture is effected upon the right handle by the intervention of a bracket, or of a bolt and socket, as seen at O, fig. 2, Plate I. The dotted lines *w, w* mark the position of the beam when attached to the body, the beam being received into the seats formed on the land-side of the palms *e, f*, as seen more distinctly at *w*, in fig. 226.

591. The body-frame being an important member of the implement, regard is paid to having it as light as may be consistent with a due degree of strength; hence, in the different parts, breadth has been given them in the direction of the strain, while the thickness is studiously attenuated in such places as can be reduced with safety. The least breadth of the sole-bar *a* is 3¾ inches; of the arm *c*, 4½ inches; and of *b*, 2¼ inches. The breadth of the sole-flange is 2 inches, the greatest thickness in any of the parts is ¾ inch, and the total weight of the frame is 30 lb.

592. *The Share.*—Figs. 227–231 inclusive are illustrations of the share and its

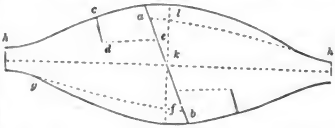


THE DETAILS OF THE SHARE.

configuration; fig. 231 is a plan, 230 a geometrical elevation of the furrow-side; and 227 a direct end view, looking forward, of which *a* is the *boss* adapted to the curvature of the mould-board, *b* the land-side flange which embraces the head on the land-side, *c* the sole-flange, embracing, in like manner, the head below, and these three parts form the neck or socket of the share, fitting closely upon the head, and being, in effect, part of the mould-board. The part *d e f*, fig. 231, forms the share proper, consisting of *d c e* the *shield*, terminating in the point *e*, and of the part *c g e* the *feather* or *cutter* running off at the point *e*. The extreme *breadth* of the share in this plough, measuring from the land-side to the point *g* of the feather, varies from 6 to 6½ inches, and its *length* in the sole, including the neck, is about 16 inches, the feather being 11 inches. The other figures, 228 and 229, are transverse sections of the share on the lines *g g* and *h h* in the respective figures, exhibiting the structure and relation of the shield and the feather, as well as the position of the cutting edge of the feather in relation to the base line of the plough represented by the line A′V′, fig. 1, Plate I., where, as will be observed, the cutting edge, through its entire length, lies within less than $\frac{1}{4}$ of an inch of the base line.

593. The share is always formed from a plate forged for the express purpose at the iron-mills, and known in the trade by the term *sock-plate.* Fig. 232 represents the form in which these plates are manufactured, the thickness being from $\frac{1}{2}$ to $\frac{3}{4}$ inch; they are afterwards cut in two through the line *a b*, each half being capable of forming a share.

Fig. 232.



A SOCK-PLATE.

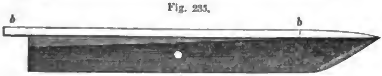
To do this, an incision *c d* is made on the short side to a depth of 2 inches, the part *a c d e* is afterwards folded down to form the sole-flange, and the part *b f g* is, in like manner, folded down to form the land-side flange. The point *h* is strengthened, when requisite, to receive the proper form of the shield and point, the latter being tipt with steel. The edge *h c* is extended to the requisite breadth to form the feather. In order to cut a sock-plate at the proper angle, so as to secure a minimum expenditure of labour and material, let a central line *h h* be drawn upon the plate, and bisect this line in the point *k*, the line upon which the plate should be cut will form angles of 70° and 110° nearly, with the line *h h*; or, mechanically, draw *k l*, equal to $5\frac{1}{2}$ inches, at right angles to *h h*, and *l a* parallel to *h h*; mark off 2 inches from *l* to *a*, and through the points *a*, *k* draw the line *a b*, which is the proper direction in which the plate should be cut.

594. *The Sole-shoe.*—The figures 233–235 inclusive are illustrative of the *sole-*

Fig. 233.

Fig. 234.

Fig. 235.

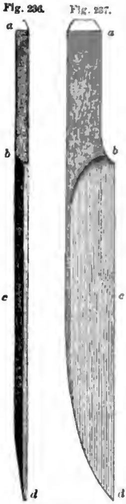


THE SOLE-SHOE.

shoe. Fig. 235 is a plan of the shoe, *a a* being the sole flange, and *b b* the land-side flange. Fig. 234 is an elevation of the same, and fig. 233 a cross section, showing the filling up of the internal angle opposed to where the greatest wear takes place. The thickness of the sole-flange at the heel *a* is $\frac{7}{8}$ inch, diminishing forward to $\frac{5}{8}$ inch at 3 inches from the point, and from thence it is thinned off to prevent obstruction in its progress through the soil. The breadth of the sole is $2\frac{1}{4}$ inches, and its extreme length $20\frac{1}{2}$ inches. The side-flange is $\frac{1}{2}$ inch thick along the edge by which it is attached to the sole, diminishing upwards to $\frac{1}{4}$ inch at the top edge, the height being $4\frac{3}{4}$ inches at the heel and 6 inches at the fore-end; weight about 14 lb. The upper land-side plate is 18 inches in length on the lower edge, being $1\frac{1}{2}$ inches longer than the corresponding edge of the sole-plate, the purpose of which will be seen in the figure of the land-side at *e*, fig. 240; the length on the upper edge is $21\frac{1}{2}$ inches. The breadth and the contour of the upper edge must be adapted to the form that may have been given to the beam *f g*. The thickness at the lower edge must agree with that of the sole-plate at *c*, and be diminished to $\frac{1}{8}$ inch at the upper edge; weight 9 lb.

595. *The Coulter.*—Fig. 236 is an edge and 237 a side view of the coulter of this plough, in which the same letters of reference are applied. The neck *a b*, by which it is affixed in the coulter-box, is about 10 inches long, though it may with all propriety be extended to *c*; the neck is usually about 2 inches in breadth and $\frac{3}{4}$ inch in thickness. The blade *b c d* varies in length according to the variety of the plough to which it belongs, from 18 to 22 inches. The breadth of the blade is usually about 3 inches in the upper part, but is curved off behind, and terminating in a point at *d*. The thickness of the back at the shoulder *b* is $\frac{3}{4}$ inch, and tapers gently downward to where the curvature of the back begins; from thence it diminishes towards the point to $\frac{1}{8}$ inch or less. It is formed quite flat on the land-side, and on the furrow-side is bevelled off towards the cutting edge, where it is about $\frac{1}{8}$ inch in thickness throughout the length of the edge.

Fig. 236. Fig. 237.



THE COULTER.

596. *The Bridle.*—Fig. 239 is a plan, and fig. 238 a corresponding elevation of the bridle, and the manner of its attachment to the beam, where *a* is a part of the beam, *b* the cross-head, and *c c* the tails of the bridle, with their arc-heads *d* embracing the beam on the two sides; *e* is the joint-bolt on which the bridle turns for adjustment to *earthing; f* is the temper-pin or bolt, and by insertion of it into any one of the holes in the arc-heads *d*, and passing through the beam, which is here perforated for the purpose, the bridle is held in any required position. The draught-shackle *g* is held in its place upon the cross-head *b* by the draught-bolt *h* passing through both parts, and the cross-head being perforated with five or more holes, the bolt and shackle can be shifted from right to left, or from left to right, for the proper adjustment of the *landing* of the plough. To the shackle is appended the swivel-hook *i*, to which is attached the main draught-bar, or swingle-tree of the yoke.

Fig. 238.

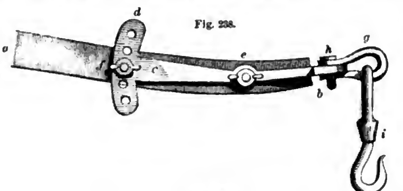
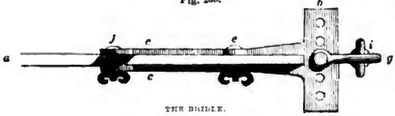


Fig. 239.



THE BRIDLE.

597. *The Land-side.*—Figs. 240 and 241 are illustrations of the land-side, fig. 240 being an elevation of the body of this plough, represented in the working position, but with the extremities cut off. The point of the share and the heel rest upon the base line at *a* and *b*, and the lines of the sole

lying between these points form the very obtuse angle which obtains in the sole of this plough; *a c* is the share, and *d b* the sole-shoe; *e* is the land-side plate,

Fig. 240.

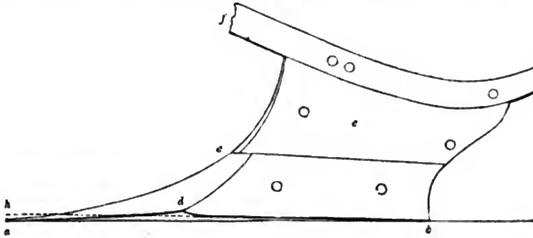
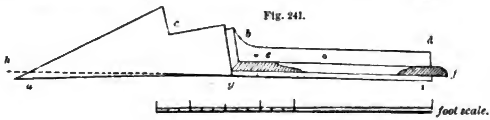


Fig. 241.



THE DETAILS OF THE LAND-SIDE.

and *f g* a part of the beam. The lines *a d* and *d b*, together with the base-line, form the very low triangle *a d b*, whose altitude at *d* does not exceed $\frac{3}{8}$ inch, or by extending the sole-line *b d* to *h*, the depression *h a* of the point of the share below this extended line will be $\frac{1}{2}$ inch nearly. Fig. 241 represents a horizontal section of the body, as if cut off at the level of the upper edge of the sole-shoe. Here *a c* is the share, *b d* the sole-flange of the body-frame, the bolt-hole at *b* being that by which the palm of the right handle is fixed to the flange; *e* and *f*, the two arms of the frame, as cut across in the section *g i*, the land-side of the sole-shoe coinciding with the land-side plane; the continuation of this line, *g i* to *h*, exhibits the inclination of the share to the land-side, which in this plough may be taken at $\frac{1}{2}$ inch.

598. The inclination downward given to the share is intended, and experience confirms the intention, to give steadiness of motion to the implement, by giving it a lengthened base on which to stand. It is evident that if a base the converse of this were given to it—convex instead of concave—so that it should rest on the point *d*; when in motion, the smallest obstruction occurring at the point of the share would give it a tendency to swerve from the horizontal line of progression, and to lose either depth of furrow or be thrown out, thus rendering the management of the plough very difficult and uncertain. Even a perfectly straight base is found not to give the requisite certainty of action, without a greater amount of exertion, as well as closer attention on the part of the ploughman. A like reason prevails for this inclination of the share *landward* as does for its *earthward* inclination, and for the steady motion of the plough the earthward is even more necessary than the landward; but there is another reason for this landward inclination, which is, that as the plough is seldom held with its land-side truly vertical, but inclining a little landward, and it being desirable to cut the furrow-slice as near as possible rectangular, the coulter has always a slight tendency landward at the point; hence it becomes necessary to give the share a like bias. By this arrangement of the parts, the incision made by the coulter will be nearly vertical. While it is admitted that these inclinations of the share

afford certain advantages in the action of the plough, it must not be concealed that the practice is liable to abuse. It has been stated, that if a different arrangement were followed, a greater degree of exertion and of attention on the part of the ploughman would be called forth: thus, if the sole and land side of the body were perfectly straight, the plough would present the least possible resistance; but as it would thus be so delicately adjusted, the smallest extraneous obstacle would tend to throw it out, unless a constant unceasing watch is kept on its movements by the ploughman. To obviate this, he gets the share set with a strong tendency to *earth*, for it is this tendency that has most effect, and greater than is requisite; and to prevent the plough taking a too deep furrow, he counteracts this by adjusting the draught-bolt to an opposite tendency; the implement will thus be kept in equilibrium, but it is obtained at an additional expenditure of horse-power. Under any such circumstances the plough is drawn at a disadvantage to the horses, by reason of an obliquity of the line of draught to the direction of motion; and this disadvantage is augmented by every undue tendency given to the parts by which the obliquity of their action is increased; or, if not so increased, the prevention of the increase will induce a deterioration in the work performed. All undue inclination given to the share, but especially in its *earthing*, will either produce an unnecessary resistance to the draught, or it will deteriorate the quality of the ploughing. It is therefore the interest of the farmer to guard against, and to prevent as much as possible, every attempt at giving any undue bias to this important member of the plough.

599. *Dimensions of the Lanarkshire Plough.*—For the purpose of comparison betwixt the action of the two forms of mould-boards we have alluded to, the concave and the convex, the *general dimensions* of the Lanarkshire plough are as follows: From the zero-point to the extremity of the heel is 4 inches, and from the zero-point forward to the point of the share is 29 inches, giving as the entire length of sole 2 feet 9 inches. Again, from the zero-point backward to the extremities of the handles, the distance is 5 feet 6 inches, and forward to the draught-bolt 4 feet 4 inches, making the extreme length of the base-line 9 feet 10 inches; but, following the sinuosities of the beam and handles, the entire length is 10 feet 6 inches. In reference to the body of the plough, the centre of the coulter-box is 15 inches, and the point of the breast-curve $6\frac{1}{2}$ inches from the zero-point, both as measured on the base-line; but, following the rise of the beam, the distance from the junction of the mould-board with the beam to the middle of the coulter-box is $10\frac{1}{2}$ inches.

600. The *heights* of the different points, as measured from the base-line to the upper line of the beam and handle, are—at the helve of the left handle the height is 3 feet 2 inches; at the same point in the right it is 3 feet; at the middle stretcher the difference in height is only $1\frac{1}{2}$ inches, but it again increases downward, till the right handle meets the sole-bar, to which it is bolted. The height of the point of the beam is 18 inches, and at the centre of the draught-bolt, at a medium of 17 inches. The lower edge of the mould-board behind is usually set at $\frac{1}{2}$ inch above the plane of the base-line, and at its junction with the share, is from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches.

601. *Of the Action of the Plough.*—The *coulter*, the *share*, and the *mould-board*, being the principal active parts of the plough, and those which supply the chief characteristics to the implement, it may be useful to the agricultural mechanic to enter into a more minute descriptive detail of the nature and properties of these members, before entering upon the duties which each in its turn has to perform in the action of cutting and turning over the furrow-slice.

602. *The Coulter.*—The coulter, in its construction, as well as in the duties it has to perform, is the simplest member of the plough. It is a simple bar, in form as represented by figs. 236-237; varying in length, according to the variety of the plough to which it belongs, from 18 to 22 inches. Simple though the form and duties of the coulter may be, there is no member of the plough whereof such a variety of opinions exist as to its position. We have shown that in practice the rake or angle which its cutting edge makes with the base-line ranges from 45° to 80°, that of its land-side face from 4° to 8° with the vertical, and that the same face, in the horizontal direction, varies from 0° to 4° with the land-side. The objects of these variations are pointed out as mere matters of taste and convention amongst ploughmen. Two points alone, in regard to position, should be considered as standard and invariable. These are, 1st, that *the land-side face of the coulter shall be always parallel, in the horizontal direction, to the plane of the land-side of the plough's body;* and, 2d, *that at the height of* 7 *inches, or of* 6 *inches, according to the depth of furrow to which the plough is adapted, the land-side face of the coulter shall be* ¼ *inch to landward, or to the left, of the plane of the land-side of the body.*

603. One other point in position is subject to a great diversity of opinion; that is, the position in which the extreme point of the coulter should stand in relation to the point of the share. In respect to *landing*, or that cause which requires the point of the coulter to be placed to landward of the share, the range of opinion is within moderate bounds, being from 0 to ¾ inch; but in the vertical direction, the range varies from ¼ inch to 2 inches; and in the longitudinal direction a like difference of opinion exists. Thus Small recommends that the point of the coulter should be 2 or 3 inches in *advance* of the point of the share, and ½ or 1 inch *above* the plane of the sole (base-line), while it should be ½ inch or 1 inch to *landward* of the land-side plane.* The position in *advance* is very much at fault; and the almost universal practice, also, of keeping the two points nearly equal in advance, condemns the practice, and points out equality as the rule. In regard to the position of the point *landward*, it is liable to considerable variation, partly from the inclination that may be given to the share, and likewise from the degree of obliquity between the coulter and the land-side. This obliquity, indeed, combined with the rule laid down, from the position of the coulter in relation to the land-side, at the height of 6 or 7 inches, is the true source from which the landward relation of the points of the coulter and share can be ascertained; hence, therefore, in whatever variety of the plough, *the coulter should have its position in regard to land determined first; and the point of the share should take its position from the coulter.* The distance to which the point of the share stands to the right of the coulter should in no case exceed ½ inch, but it were better to confine it to ¼ inch. In the *vertical* position, the advancing of the point of the coulter to, or retiring from, the share, violates no principle in the relation of the parts; but to place the coulter at an undue distance above the share, leaves that portion of the slice uncut which extends between the two points, and which must produce an undue resistance, from the part being forcibly pressed asunder, by a process like clipping, through the inclined action of the share upward. The nature of the soil, whether stony, or gravelly, or a loam, will, however, always have an effect on this point of the trimming of the plough; and as no principle is affected, there is no impropriety in giving a latitude in this direction, though we conceive that a distance of 1 inch, between the points of the share and coulter, ought to be the maximum, except in cases where the nature of the soil may demand a deviation from that distance.

* Small's *Treatise on Ploughs*, pp. 18 and 40.

604. The office which the coulter has to perform in the action of the plough is simple and uniform, being merely to make an incision through the soil in the direction of the furrow-slice that is to be raised. It is a remarkable fact, that in doing this it neither increases nor decreases the resistance of the plough in any appreciable degree. Its sole use, therefore, is to cut a smooth edge in the slice which is to be raised, and an unbroken face for the land-side of the plough to move against in its continued progress.

605. In the early works on the principles of the plough, some misconceptions appear to have been formed of the influence of the coulter, under the supposition that the coulter extending 3 inches in front of the share acted beneficially; and that giving the coulter a great rake, or a low angle with the base, made it cut the soil advantageously, and with less resistance. From a series of experiments, we have satisfied ourselves that the far advanced position is erroneous, and that the projection of the coulter before the share increases the resistance in a very sensible degree. With regard to the angle, the resistance seems not to be affected by the angle at which the edge of the coulter stands; and the analogy of a common cutting instrument* does not hold in the case of the coulter of the plough. With a razor or a knife in the hand, we make them pass through any object by *drawing* their cutting edge over the surface to be cut, in the manner as with a saw, which greatly increases the effect without any increase of force; and this holds, in all proper cutting instruments: but let the edge of the instrument be placed simply at an angle with the direction in which the stroke or cut is to be made, and in making the cut let this oblique position be retained, so that the cutting edge shall proceed paralled to its original position, without any tendency to *drawing* the edge across the direction of the cut, no saving of force is obtained. This process must be familiar to every one who uses a knife for any purpose whatever. In slicing a loaf, the operator is at once sensible that, by moving the knife gently backward or forward, he is required to exert less force, while he at the same time makes a smoother cut, than he would do by forcing the knife through the loaf, with its edge either at right angles or obliquely to the direction in which the knife proceeds. The coulter of the plough acts in the oblique direction, its cutting edge stands obliquely to the direction of motion, but has no means of drawing or *sliding*, to cross the *forward* motion; it therefore cuts by sheer force of pressure. Where elastic substances occur, an instrument cutting in this manner has some advantages. In the case of fibrous roots, for example, crossing the path of the coulter; the coulter, by passing under them, sets their elasticity in action, by which they allow the edge to slide under them to a small extent, and thus produces the *sawing* effect. In the non-elastic earths, of which soils are chiefly composed, nothing of this kind, it is apprehended, can occur; hence the angle of the coulter, as it affects the force requisite to move the plough, is of little importance.

606. We have said that the projection of the coulter in front of the share increases the resistance, and are borne out in this assertion from the result of experiments not a little inexplicable. On a subject which has of late attracted considerable attention, we were desirous of obtaining information, from experiments alone, on the actual implement; and to attain this the more fully, we determined on analysing the resistance as far as possible. With this view, a plough was prepared whose coulter descended 7 inches below the line of the sole, and fitted to stand at any required angle. This plough, *with its sole upon the surface of two-year-old lea*, and the *coulter* alone in the *soil*, the bridle having been adjusted to make it swim without any undue tendency, the force

* SMALL's *Treatise on Ploughs*, p. 18.

required to draw this experimental instrument, as indicated by the dynamometer, was 26 imperial stones, or 3¼ cwt., and no sensible difference was observed in a range of angles varying from 45° to 70°. This coulter having been removed, the plough was drawn along the surface of the field, when the dynamometer indicated 8 stones, or 1 cwt., the usual draught of a plough on the surface. Another well-trimmed plough was at work in the same ridge, taking a furrow 10 by 7 inches, and its draught was also 26 stones. On removing the coulter from this plough, and making it take a furrow of the same dimensions, the draught was still the same, namely 26 stones. The furrow thus taken produced, of course, a slice of very rough ploughmanship; and though it exhibited by a negative the essential use of the coulter—the clean cutting of the slice from the solid ground—the whole question of the operation and working effects of the coulter is thus placed in a very anomalous position. The question naturally arises, What becomes of the force required to draw the coulter alone through the ground, when, as it appears, the same amount of force is capable of drawing the entire plough with or without a coulter? A definite and satisfactory answer, it is feared, cannot at present be given to the question, and until experiments have been repeated and varied in their mode of application, any explanation that can be given is mere conjecture.

607. Since we have seen that the *same force is required to draw the plough without a coulter as with it*, and as it has been observed that the work performed without the coulter is very rough, by reason of the slice being in a great measure *torn* from the solid ground, the breast of the plough being but indifferently adapted for cutting off the slice, it is more than probable that the tearing asunder of the slice from the solid ground requires a certain amount of force above what would be required were the slice previously severed by the vertical incision of the coulter: and though we find that the force requisite to make this incision, when taken alone, is equal to the whole draught, yet there appears no improbability in the supposition that the *minus* quantity in the one may just equal the *plus* in the other. Be this as it may, the discovery of the anomaly presents at least a curious point for investigation, and one that may very probably, through a train of careful experiments, point out the medium through which a minimum of draught is to be obtained.

608. Regarding the effect of change on the angle of the edge of the coulter, though it does not directly affect the draught of the plough, it is capable of producing practical effects that are of importance. In ploughing stubble-land, or land that is very foul with weeds, the coulter should be trimmed to a long rake—that is, set at a low angle, say from 45° to 55°; this will give it a tendency to free itself of the roots and weeds that will collect upon it by their sliding upward on the edge of the coulter, and, in general, will be ultimately thrown off without exertion on the part of the ploughman. The accumulation of masses of such refuse on the coulter, greatly increases the labour of the horses. The amount of this increased labour we have frequently ascertained by the dynamometer, and have found it to increase the draught of the ploughs from 26 stones, their ordinary draught when clear, up to 36 stones, and immediately on the removal of the obstruction the draught has fallen to an average force of 26 stones. It is unnecessary to add, that the prevention of such waste of muscular exertion ought to be the care of the farmer, as far as the construction of his machines will admit of.

609. To apply a plough, with its coulter set in the position above described, to lea-land with a rough surface, would produce a kind of ploughmanship not approved of; every furrow would be bristling with the withered stems of the

unconsumed grasses; for to plough such land with a coulter set in this way, would cause its partially matted surface to present a ragged edge, from the coulter, acting upon the elastic fibres and roots of the grasses, pressing them upwards before they could be cut through. The ragged edge of the slice thus produced gives, when turned over, that untidy appearance which is often observable in lea-ploughing. To obviate this, the coulter should be set at a higher angle, by which it will cut the mat without tearing it up with a bearded edge. *Crack* ploughmen, when they are about to exhibit a specimen of fine ploughing, are so guarded against this defect that they sometimes get their coulter kneed forward under the beam so far as to bring the edge nearly perpendicular. The same cause induces the makers of the Lanarkshire plough to set the coulter with its land-side face, not coincident with the land-side plane horizontally, but at an angle with it of 4°, thus placing the *right*-hand face of the coulter nearly parallel to the land-side plane, and thereby removing the tendency, of the ordinary oblique position of the right-hand face, to produce a rough-bearded edge on the rising slice.

610. *The Share.*—We have seen that the coulter performs but a comparatively small portion of the operation required in the turning a furrow-slice. The share, however, takes a more important and much more extensive part in the process: on the functions of the share, in short, depends much of the character of the plough. Its duty is very much akin to that of a spade, if pushed horizontally into the soil with a view to lift a sod of earth; but as its action is continuous, its form must be modified to suit a continuous action; hence, instead of the broad-cutting edge of the spade, which in the generality of soils would be liable to be thrown out of its course by obstacles such as stones, the share may be conceived as a spade wherein one of its angles has been cut off obliquely, leaving only a narrow point remaining, adapted to make the first impression on the slice. A narrow point being liable to meet obstruction only in the ratio of its breadth to the breadth of the entire share, the chances of its encountering stones are extremely few; and though the oblique edge, now called the feather, has a like number of chances to come in contact with stones, yet, from its form taking them always obliquely, and the direct resistance which the body of the plough meets with on the land-side preventing any swerving to the left, such stones as come in contact with the sloping edge of the feather are easily pushed aside towards the open furrow on the right. The share thus acts by the insertion of its point under the slice intended to be raised, and this is followed up by the feather, which continues the operation begun by the point, by separating the slice horizontally from the subsoil or the sole of the furrow; and simultaneous with this, the coulter separates the slice vertically from the still solid ground. Probably the most natural impression that would occur, at the first thought of this operation, will be, that the feather of the share should be of a breadth capable of producing the immediate and entire separation of the slice from the sole; but experience teaches us that such would not fulfil all the requisite conditions of good ploughing. The slice must not only be separated, it must be gradually turned upon its edge, and ultimately still farther turned over, until that which was the upper surface becomes the lower, lying at an angle of about 45°. It is found that *if the slice were cut entirely off from the sole,* the plough would frequently *fail in turning it over* to the position just referred to; it might, in place of this, be only moved a space to the right, and fall back, or, at most, it would be liable to remain standing upon its edge; in either case the work would be very imperfect, and it has therefore been found necessary to leave a portion, usually from ½ to ¼ of

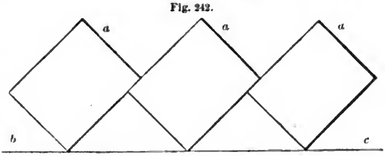
the slice, uncut by the feather of the share. This portion of the slice is left to be *torn* asunder from the sole as it rises upon the mould-board, by which means the slice retains longer its hold of the subsoil, and turning by that hold, as upon a hinge, till brought to the vertical position, after which it is easily brought into its ultimate place. The breadth of the share is thus of necessity limited to $\frac{3}{4}$ the breadth of the slice at a maximum, though its minimum, as will appear, may not exceed $\frac{1}{2}$.

611. The disposition of the *feather* comes next under notice. The feather having to perform the operation of cutting that part of the slice, below, that lies between the point of the share and the extremity of the feather, it is formed with a thin edge suited to cutting the soil; but the *position of that cutting edge* forms a principal feature in distinguishing the varieties of the plough, as before described. This distinguishing character is of two kinds; first, that which has the cutting edge lying parallel or nearly so to the plane of the sole, as in the East-Lothian plough; and, second, that which has this cutting edge elevated as it retires from the point of the share, rising at an angle with the base-line, which is found to vary from 4° to 8°, as in the Lanarkshire plough; and all the sub-varieties of these ploughs have their shares coming under one or other of these two divisions.

612. The share, in either of the forms above described, passes *under* the furrow-slice, making a partial separation of it from the sole of the furrow, rising as the share progresses—the rise, however, being confined entirely to the *land-side edge* of the slice, the furrow edge remaining still in connection with the solid ground; and the shield and back of the share being a continuation of the mould-board, the latter, in its progress forward, receives the slice from the share and passes it onward; or, more properly speaking, the plough passes under it.

613. One important consideration remains to be noticed regarding the practical effects of the two forms of feather. In the first, which has the cutting edge nearly parallel with the plane of the sole, the furrow-slice being cut below at one level over the whole breadth of the share and feather, the slice, when exposed in section, will be perfectly rectangular, as *a a a*, fig. 242, or very slightly rhomboidal, and the sole of the furrow *b c* will be perfectly level across. Such a share, then, will lift a slice of any given breadth and depth, which shall contain a maximum quantity of soil, and this result can only be attained by a share so constructed.

Fig. 242.

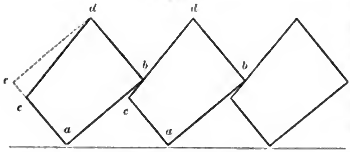


THE RECTANGULAR FURROW-SLICE.

614. In the second case, where the feather rises above the plane of the sole at angles from 4° to 8°, the feather is found sometimes to attain a height of 1 inch and $1\frac{1}{4}$ inches above that plane. In all such cases the feather is also narrow, and, supposing that the part of the slice left uncut by it may be torn asunder, in a continuation of the cut so made, the slice will have a depth at its furrow edge less by about $1\frac{1}{2}$ inches or more than at its land-side edge, as cut by the point of the share. A transverse section of this slice, therefore, fig. 243, would exhibit not a rectangular parallelogram as before, but a trapezoid, whose sides *a b* and *c d* might be each 9 inches, and its side *b d* 6 inches, and its other side *a c* $4\frac{1}{2}$ inches. A slice of this form would therefore be deficient in

the quantity of soil lifted, by a quantity contained in the triangle *d c e*, or about ⅐ part of the entire slice, and this deficiency is left by the share in the bottom of the furrow as part of the solid subsoil. The absolute quantity of soil thus left unlifted by shares of this construction, will be found to vary with the elevation that is given to the feather; but wherever this form of share is adopted, results similar to that here described will invariably follow, though they may differ in degree; but the quantity left in the bottom of the furrow will seldom fall short of 10 per cent of the whole slice. An indirect mode of removing this defect is resorted to in practice, which will be noticed under the next head of Mould-board.

Fig. 243.



THE CRESTED FURROW-SLICE.

615. The *rule* which we would recommend to be followed in order to secure the maximum of useful effect in the share, as founded on practice and observation, as well as combining the theory of the share and mould-board, is, that the length from the tail of the feather to the point of the share should be from 10 to 11 inches; that the height of the shield—the surface of the share—on the land-side, opposite to the tail of the feather, be 2½ inches above the line of the sole-shoe; that the point of the share be ½ inch below the line of the sole-shoe, and not exceeding ½ inch to landward of the land-side plane, this last point being more properly determinable from the coulter; and lastly, that no part of the edge of the feather should be more than ⅜ inch above the plane of the sole-shoe, that plane being always understood to be at right angles to the land-side plane.

616. *The Mould-board.*—Since the time that Small achieved his great improvement in the formation of the mould-board, that member has been generally held as the leading point in the plough. This, in one sense, is no doubt true; for if there is a spark of science required in the construction of the plough, it is certainly the mould-board that most requires it. Yet, for all this, we have seen a plough making work apparently little inferior to the first-rate mould-board ploughs, that had nothing to enable it to turn over the slice but a straight bar of wood. In this case, however, the work was but apparently well done, there being nothing to consolidate the slices upon each other as they fell over by their own weight. The real state of the case seems to be this, that the share impresses the furrow-slice with its form and character, and the duty of the mould-board is to transmit and deposit that slice in the best possible manner, and with the least possible injury to the character previously stamped upon it by the share. If this view is correct—and there appears no reason why it should be questioned—the mould-board is only a medium, through which the slice is conveyed from the share to its destined position. To do this, however, in the most perfect manner, the mould-board has to perform several highly important functions: 1st, The transmission of the slice; 2d, Depositing it in the proper position; and, 3d, Performing both these operations with the least possible resistance.

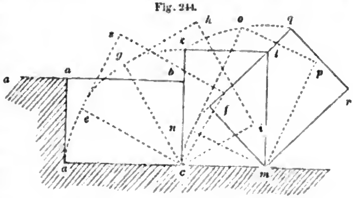
617. The *raising* and *transmitting* the slice have frequently been described as if consisting of three or more distinct movements. With all deference to former writers, we conceive it may be viewed as having only two movements, namely, cutting the slice by the share and coulter, and transmitting it to its appointed

position through the medium of the mould-board. The cutting of the slice by the share and coulter has been already discussed; we now proceed to the transmission of the slice by the mould-board.

618. The object of every mould-board is to transmit the slice in the best manner, and with the least possible expenditure of force; but, as might have been expected, we find considerable difference of opinion on both these points, arising from the variations in the form of the mould-board. In a general way, the *transmission of the slice* may be explained in the following manner.

619. In fig. 244, *a a* represents a vertical section of part of an unbroken ridge of land, and the parallelogram *a b c d* also a transverse section of an indefinitely short portion of a slice which is proposed to be raised, the breadth *a b* being 10 inches, and depth *a d* 7 inches; the line *d c* will be the bottom of the slice, or the line on which it is separated from the sole by the action of the share. The points of the share and coulter enter at *d*; and in progressing forward, the slice will be gradually raised at *d*, the point *c* remaining at rest while the parallelogram revolves upon *c* as a centre. When the share has penetrated to the extent of the feather, the point *d* of the slice will have been raised 2½ to 3 inches. By the continued progress of the plough, the parallelogram representing the slice will be found in the position *c e s f*, and again at *c g h i*. At the fourth stage, when the zero-point of the mould-board has reached the supposed line of section, the slice will have attained the vertical position *c k l m*. During these stages of this uniform process, the slice has been turning on the point *c* as on a pivot, which has retained its original position, while the point *d*, in its successive transitions, has described the quadrant *d e g k*. By the continued progress of the plough, the revolution of the slice will be continued, but it will be observed that at this stage it changes the centre of revolution from *c* to *m*; when the point *k* will have described the arc *k o*, the slice has then reached the position *m n o p*; and ultimately, when the posterior extremity of the mould-board has reached the line of section, the slice will have attained its final position *m f q r*, lying at an angle of 45°, and resting on the previously-turned-up slice.

Fig. 244.

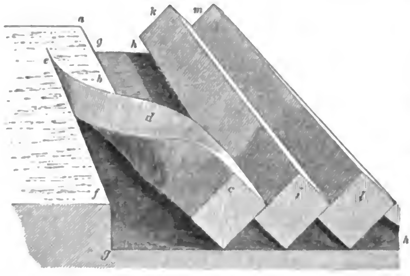


THE TRANSMISSION OF THE FURROW-SLICE.

620. The *process of turning over the slice*, therefore, approximates to a *uniform motion*, provided the parts of the plough destined to perform the operation are properly constructed. The uniformity, however, is not directly as the rectilineal progress of the plough, but must be deduced from a different function. And though the process here described refers only to an indefinitely short slice, it is only necessary to conceive a continuity of such short slices, going to form an entire furrow-slice, extending to the whole length of the field; and the lengthened furrow-slice, being possessed of sufficient tenacity to admit of the requisite and temporary extension which it undergoes while the plough is passing under and turning it over, is again compressed into its original length when laid in its ultimate position. The furrow-slice, therefore, under this process, may not inaptly be compared to the motion of a wave in the ocean, keeping in mind that the wave of the slice is carried forward in a horizontal direction, whereas the ocean-wave is vertical. But in both cases, though the wave travels onward, there is no translation of parts in the direction in which it seems to

travel. In the case of the furrow-slice movement, it appears as in the annexed perspective view, fig. 245, where *a b* is the edge of the land as cut by the preceding furrow; *c d* the slice in the act of turning over, but from which the plough has been removed; *e f* the edge of the land from which the slice *c d* is being cut; *g h* the sole of the furrow, and *i k*, *l m* slices previously laid up. A consideration of this figure will also show that the extension of the slice takes place along the land-side edge *e d* only, from *e* to where the backward flexure is given to it when rising on the mould-board; and where it is again compressed into its original length by the back parts of the mould-board in being laid down.

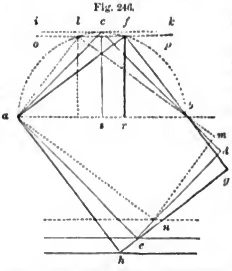
Fig. 245.



A VIEW OF THE MOVEMENT OF THE FURROW-SLICE.

621. *The Furrow-slice.*—To accomplish efficient ploughing, the furrow-slice should always be of such dimensions, and laid in such position, that the two exposed faces in a series of slices shall be of equal breadth, whether the object be a seed-furrow or intended for amelioration by exposure to the atmosphere. Furrow-slices laid up agreeably to this rule will not only present the maximum of surface to the atmosphere, but they will also contain the maximum of cubical contents, both of which propositions may be illustrated thus by fig. 246: Let *a b* represent the breadth of a 10-inch furrow-slice, and describe the semicircle *a c b* upon it as a diameter. From the well-known property of the circle, that the angle in a semicircle is a right angle,* every angle formed upon the diameter, as a base, will be right-angled, and the only isosceles triangle that can be formed within it will be that which has the greatest altitude. The triangle *a c b* possesses these properties, for produce *c b* to *d*, making *c d* equal to *a b*—the breadth of the slice, which must always be equal to the distance between the apices of two contiguous furrows. Complete the parallelogram *a c d e*, which will represent the transverse section of a rectangular slice whose breadth is 10 inches, and whose two exposed faces *a c* and *c b* lie at angles of 45°, and their breadth, as well as the area of the triangle *a b c*, will be a maximum. In order to prove this, let a section of another slice be formed, whose exposed side *a f* shall be *greater* than the corresponding side *a c* of the first slice, and let this be taken at 8 inches. From *f*, through the point *b*, draw *f g*, then will *a f b* be a right angle as before; *f g* being also made equal to 10 inches, complete the parallelogram *a f g h*, which will represent the transverse section of a rectangular slice 10 inches by 8 inches, occupying the same horizontal breadth as before, and whose exposed faces will be *a f* and *f b*. Draw the line *i c k* parallel to *a b*, and passing through the apex *c* of the triangle *a c b*; and

Fig. 246.



PROPORTIONAL AREAS OF THE FURROW-SLICE IN DIFFERENT POSITIONS.

* Euclid, 31, iii.

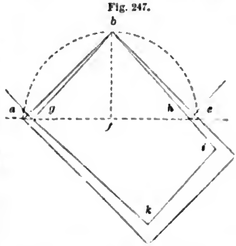
the line $o\,p$ also parallel to $a\,b$, passing through the apex f of the triangle $a\,f\,b$. Here the triangles $a\,c\,b$ and $a\,f\,b$ stand on an equal basis $a\,b$; but $a\,c\,b$ lies between the parallels $a\,b$ and $i\,c\,k$, and $a\,f\,b$ between those of $a\,b$ and $o\,p$, the altitude $f\,r$, therefore, of the triangle $a\,f\,b$, is less than the altitude $c\,s$ of the triangle $a\,c\,b$. And triangles on equal bases being proportional to their altitudes, it follows that the triangle $a\,f\,b$ is *less* than the triangle $a\,c\,b$, both in area and periphery. Suppose, again, a slice whose side $a\,l$ is *less* than the corresponding side $a\,c$, and let it be 6 inches; from l, through the point b, as before, draw $l\,m$, and construct the parallelogram $a\,l\,m\,n$, we shall have a transverse section of a third slice of 10 inches by 6 inches, whose exposed faces $a\,l$, $l\,b$ occupy the same horizontal breadth as before. Here the triangle $a\,l\,b$ lies between the parallels $a\,b$ and $o\,p$, consequently equal to $a\,f\,b$ and less than $a\,c\,b$.

622. This simple geometrical demonstration, as applicable to the slice, may be corroborated by the usual formula of the triangle. Thus the altitude of the triangle $a\,c\,b$ is $= \frac{a\,b}{2} = 5$ inches $= s\,c$, and the side $a\,c$ or $c\,b$ is $= \sqrt{a\,s^2 + c\,s^2}$; or $a\,s$ and $c\,s$ being each equal to 5 inches, $a\,c$ or $c\,b$ will $= \sqrt{5^2 + 5^2} = 7.071$ inches, which is the *depth* due to a slice of 10 inches in *breadth*, and the sum of the two exposed faces will be $7.071 \times 2 = 14.142$ inches.

623. In the triangle $a\,f\,b$, $a\,b = 10$ inches and $a\,f = 8$ inches, then $a\,b^2 - a\,f^2 = f\,b^2$, and the $\sqrt{f\,b^2} = 6$ inches. The three sides, therefore, of this triangle are 10, 8, and 6 inches, and the altitude $r\,f$ is easily found by the principles of similar triangles. Thus, in the similar triangles $a\,f\,r$, $f\,b\,r$, $a\,b : a\,f :: f\,b : f\,r$. The perpendicular $f\,r$ is therefore $= 4.8$ inches; hence the exposed surfaces are as $14.142 : 14$, and the altitudes as $5 : 4.8$. Since it turns out that $a\,l$ is equal to $f\,b$, and $a\,b$ common to both, it follows that $l\,b$ is equal to $a\,f$, and the periphery and altitnde also equal, and *less*, in all respects, than the triangle $a\,c\,b$. And so of any other position or dimensions.

624. The slice which presents a rectangular section is not the only form which is practised in modern ploughing. Of late years, and since the introduction of the changes by Wilkie on the plough, a system of ploughing has been revived* in which the great object seems to be that of raising a slice that shall present a *high shoulder*, as it has been called, or which we have ventured to denominate the *crested furrow*, fig. 243. The general impressions that prevail as to the advantages of this mode of ploughing, are, that the crested furrow affords a *greater surface* to the action of the atmosphere, and a greater quantity of cover to the seed in the case of a seed-furrow in lea. As there appears to be some degree of fallacy in the reasonings on this point amongst practical men, and as it does not appear to have been hitherto sufficiently investigated, we shall venture a few remarks, in the hope of leading others to a more full consideration of the points involved in the subject.

Fig. 247.



THE COMPARISON OF THE RECTANGULAR AND CRESTED SLICES.

625. The *crested slice*, instead of the rectangular section of the one already described in fig. 242, presents a rhomboidal, but much more frequently a trapezoidal section; indeed, the latter may be held as inseparable from the practice; but, in comparing them, we shall first take the exposed surface. In fig. 247, then, let $a\,b\,c\,d$ represent a transverse section of a rectangular slice of 10 by

* Blith's *English Improver Improved*, p. 266, edit. 1652.

7 inches, $a\ e$ the base of the triangle, whose sides $a\ b$, $b\ e$ represent the two exposed surfaces of the slice when set up with the sides at angles of 45° to the horizon, its angle at b being 90°,—its altitude $b\ f$ will be as before, $\frac{a\ e}{2} = 5$ inches. Again, let $g\ h$ be the base of the triangle whose sides $g\ b$, $b\ h$ represent the exposed surfaces of a crested slice—whose base $g\ h$, equal to $g\ k$, may be taken at 9 inches, that being the breadth at which such ploughs take their furrow. Supposing also that the cresting is such as to give an altitude, $f\ b$, of 5 inches, as in that of the rectangular slice, we shall have the sides $g\ b$, $b\ h$, from the usual formula, $g\ f^2 + f\ b^2 = g\ b^2$, and $g\ f$ being $4\frac{1}{2}$ inches, $f\ b = 5$ inches; then the $\sqrt{4.5^2 + 5^2} = 6.72$ inches $= g\ b$ or $b\ h$, being rather more than the best practical authorities for cresting ploughs give to the depth of a slice; the dimensions recommended being from $8\frac{1}{2}$ to 9 inches broad, and from 6 to $6\frac{1}{2}$ inches in depth. It will therefore always fall short in perpendicular height of the rectangular slice of 10 by 7 inches. But, allowing the height to be the same, we have two triangles $a\ b\ e$ and $g\ b\ h$ of equal height, but of unequal bases; their areas will therefore be unequal, and proportional to their bases.

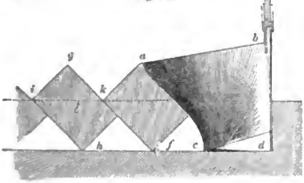
626. In bringing these two systems, however, into practice over any extent of surface, suppose a ridge of a field, the *number* of furrows of each required to turn over such ridge will be exactly in proportion to the length of the base of the triangle, or as 9 to 10. Hence, though the individual crested slices or triangles have an area *less* than that of the rectangular slice in the proportion of 9 to 10, yet the aggregate area of all the triangles, over any given breadth of surface, wherever the number of slices of the one exceeds that of the other in the proportion of 10 to 9, will be the same, but no more. The imaginary advantage, therefore, of a greater cover to the seed with a crested furrow, fails, provided the comparison is made with a plough that takes a furrow of 10 inches wide by 7 inches deep, such as the East-Lothian plough.

627. It is to be admitted, that were cresting ploughs, that cut their slices 9 inches wide, to take them 7 inches deep, and still preserve the rhomboidal or trapezoidal section, they might in that case produce an increase of cover to the seed, as compared with a rectangular slice of 9 by 7 inches. Let us refer again to fig. 247, and suppose $g\ b = 7$ inches, $g\ f$ being, as before, $4\frac{1}{2}$ inches, then $g\ b^2 - g\ f^2 = f\ b^2$, or $b\ f$ will be equal to 5.36 inches, while, by the same method, the rectangular slice of 9 by 7 inches would give $b\ f$ equal to only 4.39 inches, the crested slice in this case giving a difference of height of .97 inch, and $\frac{1}{2}$ of this, or .48 inch, of greater cover of seed. But this is not a practicable case, inasmuch as the cresting plough cannot be worked in a furrow of 9 by 7 inches, and lay the furrow-slice at an angle that would give equal exposure to both sides of the slice, whether it possess a rectangular or rhomboidal section, the true depth being 6.36 inches nearly, for a slice whose breadth is 9 inches; and the height $b\ f$ of its triangle would be, if rectangular, only 4.5 inches. Compared with itself, therefore, the plough that takes a 9-inch furrow rectangular yields $\frac{1}{4}$ inch less cover to the seed than when it raises the crested slice; but, even with the advantage of the crest, it is not better than the plough that takes a 10-inch furrow; while the former labours under other disadvantages arising from that peculiarity of structure for which it is valued.

628. In order to exhibit the difference of effect of the rectangular and the crested slices, as lifted and laid on each other by the plough, and as they affect the real intentions of tillage, we shall consider them in separate detail. Fig. 248 is an example of the rectangular slice of 10 by 7 inches: $a\ b\ d\ c$ may be taken as a transverse section of the body of the plough, the line $a\ c$ being

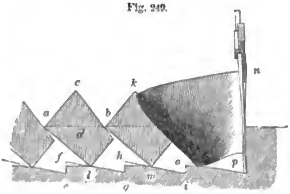
the terminal outline of the mould-board, *a f* a section of the furrow-slice which is just being laid up, and *g h* a slice previously deposited. In the triangle *i g k*

Fig. 248.



THE EFFECTS OF A RECTANGULAR FURROW-SLICE

Fig. 249.



THE EFFECTS OF A CRESTED FURROW-SLICE

the base *i k* is 10 inches, being always equal to the breadth of the slice, the angle at *g* a right angle, and the sides *i g*, *g k* each equal to 7.071 inches, the perpendicular height *g l* being 5 inches, as demonstrated in par. 621. Fig. 249 is a similar representation of a cresting plough, with its effects on the slice and the subsoil; *k n p o* is a section of the plough, *k m* a section of a slice in the act of being deposited on the preceding slice *c l*. Here the slices are trapezoidal, as they are always cut by this species of plough; and from this configuration of the slice, the broader sides are not parallel, nor do the conterminous sides of the adjacent slices lie parallel to each other in the transverse direction. The side *b c* lying at an angle of 48° with the base *a b*, while the side *b m* makes the opposite angle at *b* only 41°, the angle at *c* being 84°, and the triangle *a b c* isosceles. The base *a b* of the triangle *a b c* is now supposed to be $8\frac{1}{2}$ inches—the breadth recommended for a seed-furrow, and the side *a c* $6\frac{1}{2}$ inches, the opposite side *l h* being $4\frac{1}{2}$ or 5 inches. The base *a b*, when bisected in *d*, gives $a\ d = 4.25$ inches, and since $a\ c^2 - a\ d^2 = c\ d^2$, *c d* will be 4.918 inches, which is less than given by the former demonstration of the crested slice; but we have observed cases still more extreme, where, still referring to fig. 249, *a b* was only $7\frac{1}{2}$ inches, but the angle at *c* became so acute as 75°; yet with these dimensions *c d* is still under 5 inches; hence in all practical cases, with a furrow less than 9 inches in breadth, the result will be a reduction in the quantity of cover for seed.

629. One other point remains to be noticed in reference to the two forms of furrow-slice. We have seen that the rectangular slice necessarily implies that the bottom of the furrow shall be cut upon a level in its transverse section, fig. 242; while the slice that is cut by the cresting plough leaves the bottom of the furrow with a sloping rise from the land-side towards the furrow-side at every slice, and this rise may range from 1 to $1\frac{1}{2}$ inches or more. Returning to fig. 248, the serrated line *f h o* exhibits a transverse section of the surface of the subsoil from which the soil has been turned up by the cresting plough. The triangular spaces *e f g*, *g h i* represent the quantity of soil left by such ploughs at the lifting of each slice. These quantities may amount to $\frac{1}{4}$ of what the slice ought to be, and are thus robbed from it, and left adhering to the subsoil, except in so far as they may be rubbed down by the abrading action of the lower edge of the mould-board, as at *f* and *h*, and the portions of soil so rubbed off are thrust into the spaces under the edge of the slices as they are successively laid up. This last process may be readily observed at any time when the plough is working in tough land or in lea. With a cresting plough the spaces *f*, *h*, *o* will be seen more or less filled up with crumbling soil; while, with

the rectangular plough, the corresponding spaces will be left nearly void. We should decidedly say that the filling-in of these voids cannot be as beneficial to the land as if the $\frac{1}{4}$th here left below had been turned up with the slice; and what is thus left is more frequently left adhering to the subsoil than it is to be found stuffed under the edge of the slice. Under any view, the system of the crested furrow-ploughing is not unworthy the serious consideration of the farmer.

630. In considering this question, there are two points deserving attention. 1st, The immediate effects upon the labour of men and horses. It may be asserted generally, that all ploughs adapted to form a crested furrow are heavier in draught than those which produce the rectangular furrow. This seems a natural inference from the manner in which they work—the tendency that they all have to *under*-cut by the coulter; the narrow feather of the share leaves more resistance to the body in raising and turning the slice; and not least, the small ridge left adhering to the bottom of the furrow, if rubbed down and stuffed under the slice, is performed by an unnecessary waste of power, seeing that the mould-board is not adapted for removing such adhering obstructions. 2d, The loss of time and labour arising from the breadth of furrow, compared with those ploughs that take a 10-inch furrow. Thus, in ploughing an imperial acre with a 10-inch furrow—leaving out of view the taking up of the closing of the open furrows, the turnings, &c.—the distance walked over by the man and horses will amount to 9.9 miles nearly; with a 9-inch furrow the distance will be 11 miles; with $8\frac{1}{2}$-inch furrow it will be $11\frac{1}{2}$ miles or thereby; and with a $7\frac{1}{2}$-inch furrow $13\frac{1}{4}$ miles nearly.

631. It may, therefore, be of importance for the farmer to weigh these considerations, and endeavour to ascertain whether it is more for his interest that his ploughing should be essentially well done, and with the least expenditure of power and time, or that it should be done more to please the eye, with a high surface-finish, though this may perhaps be gained at a greater expenditure of power and time; while the essentials may in some degree be imperfectly formed. We would have no hesitation to prefer the well-done work, and the saving of power and time, to mere external finish.

632. On this part of the subject we cannot refrain a passing remark on the very laudable exertions that have been made all over the country in producing that emulation amongst our ploughmen, which has been so successful in producing excellence in their vocation amongst that useful class of agricultural labourers, as to give them a pre-eminence over all others of their class in any country—we mean the institution of *ploughing-matches.* While we offer our ardent wishes for a continuance of the means which have raised the character of the Scottish ploughmen, we cannot prevent doubts rising in our mind, that, however good and beneficial these competitions are calculated to be, if the exertions of the class are properly directed, yet the best exertions of both the promoters and the actors may be frustrated by allowing a false taste to be engendered amongst the operatives. That such a false taste has taken root, we have no doubt; and the results of it are appearing in the spread of opinions favourable to that kind of ploughing which to us appears not much deserving of encouragement—the high-crested system. We have observed, at various ploughing-matches, that the prize was awarded to that kind of ploughmanship which exhibited the highest surface-finish, without reference to the groundwork of it; and we have compared by actual weight, all crumbs included, the quantities of soil lifted by ploughs that gained prizes with others which did not, because their work did not look so fine on the surface; and we have found that the one to whom the prize was awarded had not lifted so much soil by $\frac{1}{10}$ as some

of those that were rejected. We are far from intending, by these remarks, to throw discredit on ploughing-matches; on the contrary, we would wish to see them meet with tenfold encouragement, and also to see many more than are usually met with, of the good and the great of the land, assembled at those meetings, to encourage and stimulate by their presence and liberality the exertions of the competitors in such interesting and useful exhibitions.

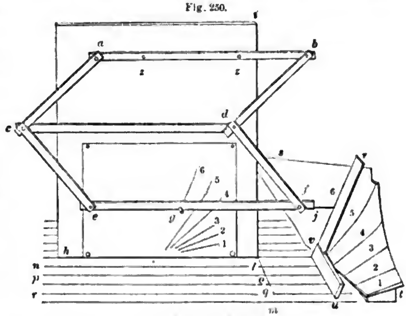
633. *The Principles and Formation of the Mould-board.*—Of the various individuals who have written upon the plough and the formation of the mould-board, Bailey of Chillingham and Small of Berwickshire are perhaps the only two who have communicated their views in a practical shape; and even in their descriptions there is somewhat of ambiguity and uncertainty, but such may be inseparable from the subject. Many other nameless artisans have varied the mould-board until almost every county has something peculiarly its own, and each district claims for its favourite all the advantages due to perfection.

634. We have been at great pains to analyse a considerable number of these varieties; and as the subject is not unimportant in a work of this kind, we have selected a few of the best known, and of highest character, as objects of comparison.

635. The method adopted to obtain a mechanical analysis of these mould-boards has been simple, but perfectly correct; and as the principle may be applied to the attainment of counterparts of other objects, perhaps more important than a mould-board, it may be deserving of a place here. As a matter of justice also to the fabricators of the different mould-boards here exhibited, we are desirous to show the principle on which these transcripts of their works have been thus brought forward in a new form, and in contrast with each other.

636. The instrument employed for this purpose is a *double parallelogram* or *parallel ruler*, as represented in fig. 250, which is a perspective of the apparatus. The bars *a b*, *c d*, *e f*, are slips of hardwood about 3 feet long, or they may be of any convenient length, and $1\frac{1}{2}$ inches broad by $\frac{3}{8}$ inch thick, each of which is perforated at *a*, *b*, *c*, *d*, *e*, *f*, the perforations being exactly equidistant in all the bars. Four similar bars, of about half the length, are perforated also at one uniform distance, and the seven bars thus prepared are jointed together upon brass studs, and secured so as to move freely at every point, but without shake on the studs. The form when constructed is that of the two parallelograms *a b d c* and *c d f e*. In the end of the bar *e f* a stout wire-pointer *j* is fixed, of about 6 inches in length, lying in the plane of the instrument, and parallel to the edge of the bar. In a continuation of this parallel upon the bar *e f*, a socket capable of retaining a pencil or tracer is fixed anywhere at *g*. The instrument so formed is fixed upon a flat

Fig. 250.



THE PARALLEL RULER.

board *h i*, of about 3 feet square, by means of two screw-nails *z z* passing through the bar *a b*, in a position parallel to the lower edge of the board; thus leaving all the other bars at liberty to move upon their joints; which completes the instrument. From the well-known properties of the parallelogram, as applied to the pantograph and the eidograph, it is unnecessary to demonstrate that whatever line or figure may be traced with the pointer *j*, will be faithfully repeated by the tracing-pencil *g* upon any substance placed before it, and of the same dimensions as the original.

637. Another board, or table, or a level platform, is now to be selected, and a line *l m*, which may be called the fundamental or leading line drawn upon it. This line, to an extent of 3 feet or more, is divided into any number of equal parts, but in this case the divisions were 3 inches each; through these points of division are drawn the straight lines *l n*, *o p*, *q r*, &c., indefinitely on each side of the line *l m*, and at right angles to it. The board carrying the instrument is provided with a foot behind, that keeps the face of the board always perpendicular to the platform on which it stands. The plough with the mould-board about to be analysed is now set upon the table or platform upon which the leading line and the divisions have been laid down, the land-side of the plough being set parallel to the leading line, and at any convenient distance from it suited to the instrument; presenting the mould-board in the position *s t*, and so placed in reference to the lines of division that the zero-line shall coincide with one of them, provided the extremities do not overreach the divisions either way, the land-side of the plough being at the same time perpendicular. The instrument is now brought towards one extremity of the mould-board, and placed upon that parallel of the divisions that come nearest to the extremity, as No. 1, the edge *l i* of the instrument coinciding with the leading line *l m*. A sheet of paper having been now fixed upon the board *h i* of the instrument, and a tracing-pencil inserted in the socket *g*, the operation of tracing commences. The tracing-point *j* is passed in the vertical direction over the surface of the mould-board, tracing along a line No. 1, the pencil *g* at the same time tracing a corresponding line No. 1, on the paper, which will be an exact outline of the face of the mould-board at that division, supposing the mould-board to be cut by a transverse section in that line. The instrument and board are now to be moved one division upon the leading line *l m*, the coincidence of the edge *l i* of the board with that line being still preserved. The tracing-point *j* is again made to pass vertically over the face of the mould-board at No. 2, when the pencil *g* will trace on the paper a second line No. 2. This process, repeated at each successive division, 3, 4, 5, 6, &c., the corresponding lines, 3, 4, 5, 6, &c. on the paper will be traced out, exhibiting a series of perfect sectional lines of the mould-board, each line being that which would arise from an imaginary vertical plane cutting the body of the plough at right angles to its land-side at every 3 inches of its length. To prevent any inaccuracy that might arise from a misapplication of the tracing-point *j* to the oblique surface of the mould-board, a straight-edged ruler, in form of a *carpenter's square u v x*, is applied to the mould-board. The stock *u v* of the square being placed on the platform, and parallel to the line *l m*, which brings the edge *v x* always into the vertical plane, and the tracing-rod *j* must be kept in contact with this edge, while it traverses the face of the mould-board at each successive section.

638. This mode of analysis, it is to be observed, has not been adopted from its having any relation to the principles on which the different mould-boards have been constructed, but because it presents an unerring method of comparing

a series of sectional lines of any one mould-board with those of any other; hence it affords a correct system of comparison. But it is not merely a comparative view that is afforded by it, for a groundwork is thus afforded from which the mechanic may, at any time or place, construct a *fac-simile* of any mould-board, the analysis of which has been made after this manner.

639. The results of the analysis of the mould-boards of the ploughs we have been speaking of, as taken by this method, are given in the following figures. Plate II., fig. 1, is a geometrical elevation in a plane parallel to the land-side of the mould-board of the East-Lothian plough, *l m* being its base-line. The perpendicular lines of division, commencing from the lines *o o* the zero, and extending right and left, are the lines of section. Those to the right or fore-end of the mould-board, marked *a a*, *b b*, &c., and those to the left 1 1, 2 2, &c. The curved line *x y z* represents the path described on the face of the mould-board by the lower land-side edge of the furrow-slice, as the mould-board passes under it; this line we shall call the *line of transit*. Fig. 2 is a front view in elevation of the mould-board of the same plough, and corresponding to fig. 1; *k m* is the base line of the plough; *m g* is the land-side plane in a vertical position; *m* is also the place of the point of the share; and *h i* the line of junction between the neck of the share and the mould-board; the remaining lines beyond *h i* exhibit the outline of all the sections taken by the instrument in reference to the lines in fig. 1. Thus, *o o g m* is the section of the entire body of the plough in the plane of the zero-line, *o y o* being the outline of the mould-board at this section, and *y* the zero-point; *a a g m* the first section forward from the zero line, *b b g m* the second, and so on. In like manner 1 1 *g m* is the first section backward from the zero, 2 2 *g m* the second, and so on; each section so lettered and numbered having relation to the divisions carrying the corresponding letters and numerals in fig. 1. The entire series of lines 1 1, 2 2, &c., and *a a*, *b b*, &c., thus form a series of profiles of the mould-board, supposing it to be cut vertically by planes at right angles to the land-side of the plough. In fig. 2, also, the dotted line *m x y z* represents the path of the slice or line of transit, as in fig. 1, and *z k* represents a transverse section of the *slice* as finally deposited by the mould-board.

640. Figs. 3 and 4 exhibit in the same manner the mould-board of the Lanarkshire plough, the divisional and sectional lines being all laid off in the same manner from the zero-line as in the example just described of the East-Lothian plough, and the zero-point *y* in the line *o y o*, which is 9 inches from the plane of the land-side. Fig. 4 bears also the same relation to fig. 3, and the letters and numerals in these have the same relation and value as in figs. 1 and 2 of the East-Lothian plough.

641. With reference to the characters of these different mould-boards, it may be remarked of the *East-Lothian* mould-board, fig. 2, Plate II., that those portions of the sectional lines lying between the lower edge and the line of transit are essentially straight, the two lines beyond the zero-line backward excepted, these being slightly concave towards the lower edge; and although the lines before the zero-line and above the line of transit are concave, that part of the surface has no effect upon the furrow-slice. It is likewise to be observed, that the parallelogram *k y*, which represents a section of the slice when brought to the vertical position, has its upper angle *y* only touching the zero-line, and no other part of the side of the parallelogram in contact with the zero-line of section *o y o*; hence the mould-board, by its pressure being exerted chiefly against the upper edge of the furrow-slice, will always have a tendency to abrade the crest of its rectangular slice in its progress over the mould-board.

642. The *Lanarkshire* mould-board, figs. 3 and 4, Plate II., has all its lines convex, the terminal edge excepted, which is nearly straight below, but preserves the convexity as it approaches the line of transit. Even above the line of transit the convexity is continued, and though not affecting the furrow-slice, it gives, in appearance, a still more decided character of convexity; and by thus making the upper edge of the mould-board retire, gives a long rake to the breast of the plough. It will be readily conceived that this mould-board, from the convexity of all its sectional lines, is essentially formed for turning up a crested furrow, more especially when the form of its share and the position of its coulter are considered. These last, being formed for cutting the slice with a very acute angle, will deliver it to the mould-board; and, from the form of the latter, the slice will pass over it uninjured; for the pressure upon the mould-board will be always greatest upon those parts of the surface of the slice lying within the edge, preventing thereby the abrasion of that tender part. These circumstances are clearly seen from the relation of the section of the furrow-slice *k y* as applied to the zero-line *o y o*, the point of contact lying considerably within the angle at *y* of the slice; and the same relation holds throughout the entire transit, up to the delivery of the slice in the ultimate position *k z*.

643. With the foregoing mould-boards, it will be observed that the section of the furrow-slice, in its ultimate position, seems to encroach upon the tail of the mould-board; and this is to be understood as arising from the circumstance of the slice being represented as incompressible, and unabraded below or above. In practice, the slice is pressed downward on the angle at *k*, and pressed home upon the preceding slice, so as to bring the face of the slice simply in contact with the terminal line of the mould-board instead of the apparent mutual interpenetration exhibited in the figures.

644. From the examples here given of the forms of mould-boards, and the effects which they produce when combined with any particular form of share and position of coulter, it will be easy to draw a conclusion as to the kind of work that will be performed by any plough that comes under our observation, and that without any previous knowledge of its merits; keeping in mind that the *ultimate form of the furrow* will always depend on the form of the share and position of the coulter, that the passage of the furrow-slice over the mould-board will have but a very partial effect on the form of the slice, and that this effect will be greater or less according to the form of surface. Thus, a slight convexity of surface, immediately below the line of transit, will with greater certainty secure the transit of the slice without injury to its edge, than may be expected from a surface which has a concavity crossing the line of transit, though it may be obtained, as in the East-Lothian plough, with a straight-lined mould-board; but it will be more certainly obtained if the share is narrow, as in the Lanarkshire; though this last expedient will induce disadvantages in point of draught, and risk of losing the effect, by any undue placement of the coulter. These disadvantages may arise from the coulter not being sufficiently set to landward, thereby admitting the breast of the plough to scrape upon the land, and send a small portion of earth along the mould-board, accompanying the edge of the furrow-slice, which may have the effect of abrading it so much as to injure the *appearance* of the work, though not, in fact, affecting its efficiency.

645. Having thus endeavoured to establish some data by which the agricultural mechanist, whether amateur or operative, may be assisted in determining from observation what practical effects may be expected to result from any form of mould-board and share, we proceed to mention some rules by which he

may form a mould-board on what we may conceive to be the true principle, but upon which may be engrafted such deviations as taste or other circumstances may require.

646. Those writers who contributed to the improvement of the plough in the early stages of its modern history, laboured at a time when mould-boards of wood only were employed. Hence, their instructions related to the formation of that material alone, into mould-boards. Later writers have followed in nearly the same course, and have given rules for forming a mould-board out of a block of wood, of sufficient dimensions to contain all the extremities of the proposed fabric. The change now pervading this branch of mechanics, wherein the introduction of cast-iron has become universal, precludes the necessity of falling back upon any of the old rules; what the agricultural mechanic is now required to furnish being not a mould-board, but, in the language of the foundry, a *pattern*, from which castings are to be obtained perfect fac-similes of the original pattern, and which may be repeated *ad libitum:* from this last circumstance it follows that the making of a pattern will be a comparatively rare occurrence, and one which he will seldom be called upon to perform. It nevertheless appears desirable that a knowledge of the construction of such a fabric should be communicated in a manner that may enable an ordinarily skilled mechanic to construct a pattern when required, with accuracy and certainty of effect.

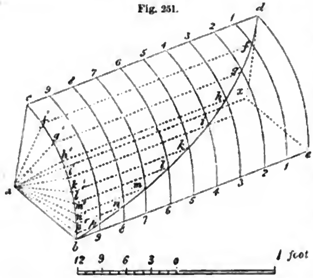
647. Very considerable discrepancies exist in the form given to mould-boards, and there is no doubt that peculiarities of soil may demand variations in form; but the propriety of such wide deviations may be called in question, and the actually required deviation brought within very narrow limits. It appears, indeed, that one form may be brought to answer all required purposes, if aided by a properly adjusted share and coulter.

648. *Theoretical Mould-board.*—From a careful study of the foregoing analytical diagrams, and from comparison of numerous implements and their practical effects, together with a consideration of the dynamical principles on which the plough operates, we have been led to suggest a theoretical form of mould-board, which seems to fulfil all the conditions required in the investigation, and which is capable, by very simple modifications, of adaptation to the circumstances of the medium on which it works. In the outset, it is assumed that the soil is homogeneous, and that it possesses such a degree of tenacity and elasticity as to yield to the passing form of the plough, and to resume, when laid in the due position, that form which was first impressed upon the slice, by the action of the share and coulter; the second consideration being the cutting of a slice from the solid land. In a theoretical view, this must be an operation through its whole depth and breadth; hence the share is conceived to be a cutting edge which shall have a horizontal breadth equal to the breadth of the slice that is to be raised, and that the face or land-side of the coulter shall stand at right angles to this. Another consideration is, that the slice now supposed to be cut has to be raised on one side, and turned over through an angle of 135°, the turning over being performed on the lower right-hand edge, as on a hinge, through the first 90°, the remaining 45° being performed on what was at first the upper right-hand edge (figs. 244-245.) The slice, in going through this evolution, has to undergo a twisting action, and be again returned to its original form of a right prism. To accomplish this last process, it is evident that a *wedge, twisted* on its upper surface, must be the agent; and to find the form and dimensions of this wedge, is solving the problem that gives the surface of the mould-board required.

649. We have seen, fig. 244, that the slice, in passing through the first 90°, describes the quadrant with its lower edge, and in doing so, we can conceive a

continued slice to form the solid of revolution *a b c d e*, fig. 251, which is a quarter of a cylinder, as shown here in isometrical perspective; the radius *a b* or *a c* being equal to the breadth of the slice. We have next to consider the angle of elevation of the twisted wedge; and in doing this, we must not only consider the least resistance, but also the most convenient length of the wedge. In taking a *low* angle, which would present, of course, proportionally little resistance, it would, at the same time, require a length of mould-board that would be highly inconvenient, seeing that the generating point, in any section of the slice, must ultimately reach the same height, whether by a low or a higher angle. From experience we find that, from the point of the share to that point in the plough's body where the slice arrives at the perpendicular position, and which we have named the zero-point, 30 inches form a convenient length. The length *c d* of the solid is therefore made equal to 30 inches or more, and this being divided into ten equal parts, the parallels 1 1, 2 2, 3 3, &c., are to be drawn upon the cylindrical surface; and between the points *b d*, a curve has to be described that shall be the line of transit of the slice. After investigating the application of various curves to this purpose, we have found that a circular arc is the only one that can be adopted. It presents the least attainable resistance in the first stages of the ascent, where the force required to raise the slice is the greatest; and in the last stages, where the force of raising has vanished, leaving only what is necessary to turn the slice over, the resistance is at the greatest; and, above all, the circle being of equal flexure throughout, it is in every way best adapted to the objects here required.

Fig. 251.



THEORETICAL PRISM FOR THE GENERATION OF THE MOULD-BOARD.

650. To determine the radius of curvature of this arc, we must evolve the cylindrical surface *c b d e*, and from it construct the diagram, fig. 252. Draw *e b* equal to *c d* of fig. 251; *e d* equal to the length of the arc *c b* or *d e*, and at right angles to *e b*; divide *e b* into ten equal parts, and from the points of division draw the ordinates 1 *f*, 2 *g*, 3 *h*, &c., parallel to *e d*; from *b* set off 10 inches for the length of the share along the line *b e*, which will fall 1 inch beyond the division 7, and at this distance draw the line parallel to 7 *m*; upon this set off a distance 7 *m* of 2½ inches; and through the three points, *d*, *m*, *b*, describe an arc of a circle, whose radius will be found equal to the circumference of the cylinder of which *a b c*, fig. 251, is a quadrant. The circular arc thus found is now to be transferred to the cylindrical surface *c b d e*, fig. 251. The transfer may be performed by drawing the arc on paper, and the paper then laid over the cylindrical surface in such a manner that the points *b*, *m*, *d*, fig. 252, shall be brought to coincide with the points *b*, *m*, *d* of the cylindrical surface, fig. 251; when the remaining points *f*, *g*, *h*, *i*, or any number more, may be marked on the cylindrical quadrant by pricking through the paper with a pointed instrument at short

Fig. 252.

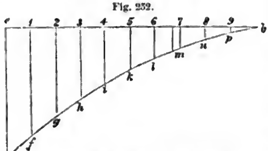
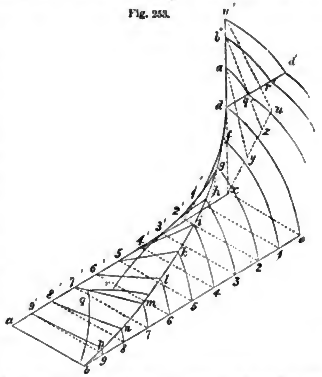


DIAGRAM TO DETERMINE THE RADIUS OF CURVATURE OF THE MOULD-BOARD.

intervals along the arc; or, the length of the ordinates 1 *f*, 2 *g*, 3 *h* of fig. 252, may be transferred to the corresponding parallels of fig. 251, when the lengths of the ordinates will cut the parallels in the points *f*, *g*, *h*, &c. In either case, the curve can now be traced through the points *b*, *p*, *n*, *m*, &c., on the cylindrical surface. Through the points *b*, *p*, *n*, *m*, &c., draw the dotted lines *f f'*, *g g'*, *h h'*, &c., parallel to *c d* or *b e*, and from the centre *a* draw the radii *a f'*, *a g'*, *a h'*, &c.; the unequal divisions of the arc *c b* will thus show the proportional angles of ascent of the slice along the line of transit now found, *b*, *p'*, *n'*, &c., for each division of the length; while the degree of flexure in the curve or line of transit remains uniform by the same, from any one point, to any other equidistant point.

Fig. 253.

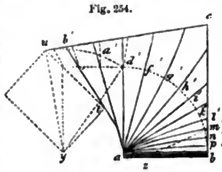


THE TWISTED WEDGE OF THE MOULD-BOARD CUT OUT OF THE PRISM.

651. To convert the prism thus prepared and lined off into that of the twisted wedge, we have only to cut away that portion of it contained within the boundaries *a*, *b*, *c*, *d*, *x*, preserving the terminal edges *a b*, *a x*, and *d x*; and the prism will thus be resolved into a form represented by a portion *a b d x e*, of fig. 253, also in isometrical perspective. Of this figure, *a b d x* is the true theoretical surface of the mould-board, from the edge *a b* of the share to the zero-line *d x*; *a b e x* being the sole; the curve *b p n m l*, &c. the line of transit of the furrow-slice; and the triangles 1 *f* 1′, 2 *g* 2′, 3 *h* 3′, 4 *i* 4′, &c. the vertical planes, supposed to cut the solid thus reduced in the divisions 1, 2, 3, 4, &c. to the height of the line of transit, as in the analytical sections of the mould-boards.

652. The surface now completed can only raise the slice to the perpendicular position; and to complete the operation, we have to carry the twisted wedge back till it shall place the slice at the angle of 45°. To do this we have to extend the original prism, or suppose it to have been at first sufficiently elongated towards *d d'*, fig. 253, and to superimpose upon its flat side the portion *d d'*, *u x*, or *a d' u* of fig. 254. The part *d d' u x* is now to be worked off into a part of a new cylindrical surface, whose radius is *y d'* or *y u*, fig. 254, and upon this surface, the line *d' u*, fig. 254, is to be drawn a tangent to the curve *b d'* at *d'*. A continuation of the divisions of 3 inches is to be made upon the line *d d'*, fig. 253, and the parallels *a' q*, *b' r*, and *u' d'*, continued on the cylindrical surfaces. Whatever portion of the superimposed piece *a d' u* may be found to fall within the small arc *a t*, fig. 254, is to be cut away, forming a small portion of an interior cylinder concentric to the point *y*, which being done, the remaining portions of the superimposed piece are to be cut away to the dotted lines *d x*, *a' y*, *b' z*, *u' u*, of fig. 253, or, what is the same thing, to the lines *d' a*, *a' a*, *b' t*, and *u t*, of fig. 254, forming tangents to the curve *a t*, and which will complete

Fig. 254.



TRANSVERSE SECTION OF THEORETICAL MOULD-BOARD.

the surface of the twisted wedge through its entire length, and to the height of the line of transit, producing what we conceive to be the ***true theoretical surface*** of the mould-board.

653. Fig. 254 exhibits distinctly, in the quadrant *a b d'*, the inequality of the angles of ascent for the slice, where the radii *a p'*, *a n'*, *a m'*, &c. represent the ascents to the corresponding divisions of length in the transit of the slice through the curve *b d' u*, which represents the periphery of the cylindrical surfaces at the line of transit. The parts of the figure lying above that line represent those that must be superimposed above the quadrantal portion of the cylinder, to complete the upper regions of the mould-board: these parts, acting merely as a preventive against the overfall of soil into the waste of the plough, are of less importance as to form than those just described, but are quite necessary in the practice of ploughing. The parallelogram *y d'* exhibits the relation in which the furrow-slice stands to this form of mould-board, when the slice has been raised to the perpendicular, and *y u* in its ultimate position.

654. Although we hold this to be a true theoretical form, it is not in this state fit to be employed as a practical mould-board, but the steps to render it so are very simple. The broad shovel-mouth *a b*, fig. 253, would meet with obstructions too numerous to admit for a moment of its adoption in practice; but we have only to remove the left-hand portion of the edge *a b*, in the direction *b q*, making the breadth *q m*, 6½ to 7 inches broad; that portion also contained within *q r* 3' is to be cut away, leaving *m r* about 4 inches broad; *b q r m* will then represent the share; the mould-board being thus of the prolonged form in the fore-part. And though this form has no peculiar advantage over the truncated, in respect to working, it is better adapted to admit of the body being constructed of malleable iron, a practice which, though more expensive, is certainly the preferable, by reason of its greater durability, and being less liable to fracture through the effect of shocks, when stones or other obstructions are encountered.

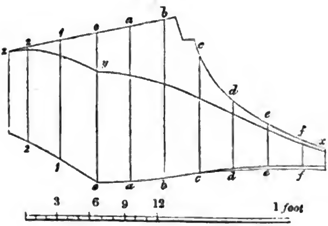
655. Besides the removal of these parts of the theoretical mould-board, other slight modifications are admissible. When the parts have been cut away as described, the *edge b q* of the share will be found too thick for a cutting edge. If brought to a proper thinness, by removing the parts *below*, making the edge to coincide with the curved surface, the share so prepared would have the character that belongs to the cresting ploughs (par. 614.) The lower edge of the mould-board from *r* to 2' would be also rather high, and would present unnecessary resistance to the lower side of the slice; both parts, therefore, require to be reduced. The *surface* of the feather *b q* is to be sloped down till it becomes straight between the points *b* and *q*, *q* not being more than ¼ inch above the plane of the sole, as at the dotted lines *m' z* in fig. 254. The lower edge of the mould-board is also to be rounded off, as shown by the dotted lines along the lower edge from *h* to *o* in fig. 256. To prevent the abrasion of the edge of the slice in passing over the mould-board, it will also be expedient to make the lines from *d'* to *u*, in fig. 254, fall in, from below the line of transit upwards, as shown by the dotted lines at *d'*, *a'*, *b'*, *u*.

656. Other modifications may, if required by peculiar taste or otherwise, be given to this form of mould-board. After the points *b p n m*, &c. have been determined upon the cylindrical surface, fig. 251 or 253, if, in cutting away the parts above *a b*, fig. 253, instead of reducing the surface to the straight lines 9 *p*, 8 *n*, 7 *m*, &c. we leave the surface slightly convex upon all these lines, a surface will be produced as represented by the dotted sectional lines at *d'*, *a'*, *b'*, and *u*, of fig. 254, and by becoming slightly either recurved above the line of

transit, as at 1, 2, *z*, in fig. 256, or with continued convexity, as in fig. 4, Plate II., the surface so produced would deliver the slice without risk of injury to the edge; which, though not of vital importance, is always an object in the estimation of the ploughman who performs his work with taste. The same modification would also, in the opinion of many agricultural machine-makers, render the mould-board more efficacious in the working of stiff clay-soils.

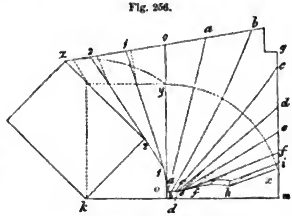
657. Fig. 255 represents an elevation of the new mould-board, and fig. 256

Fig. 255.



ELEVATION OF THEORETICAL MOULD-BOARD.

Fig. 256.



SECTION OF THEORETICAL MOULD-BOARD—SCALE AS IN FIG. 255.

the analytical section of the same, taken in the same manner as described for those on Plate II., and having the same letters of reference. In the present case, the sectional lines are all straight to the height of the line of transit *x y*; above that line and before the zero-line they are slightly concave, though this is not imperative; but behind the zero-line they are convex from a little below the line of transit, as shown by the dotted portions of the lines from 1, 2, *z*. The parallelogram *k y*, being a section of the furrow-slice when in a vertical position, will be seen to coincide exactly with the zero-line at *y*, as it will do through the whole passage of the slice from *y* to *z* 2.

658. Judging from the trials that have been made of this mould-board, and from the *uniform brightening of its surface* after a few hours' work, it promises to possess a very uniform resistance over its whole surface, which is a principal object to be aimed at in the formation of this member of the plough.

659. *The Mould-board Pattern.*—The instructions thus given refer solely to the formation of the theoretical surface of the mould-board, including that of the share; but in the construction of a *pattern*, from which mould-boards are to be cast, the process is somewhat different, though based on the principles above laid down.

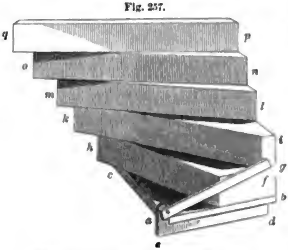
660. In proceeding with this, therefore, the quadrant of the cylinder upon which the whole problem is grounded may or may not be prepared. If it is to be employed, then the first process is exactly as before described in reference to the quadrant, fig. 251, which must be formed and lined as there described; but the same process may be pursued from lines alone, without the intervention of the solid, and in the following manner:—Having described the quadrant of a circle, as *a b c*, fig. 251, of 10 inches radius, construct the diagram fig. 252, as before directed in par. 650, the entire length *e b* being 30 inches, divided into equal parts of 3 inches each. The arc *b d* is then to be drawn through the points *b p n m*, &c. which points, instead of being a transfer, as before described, from the quadrant, may here be drawn at once with a beam-compass touching the three leading points *b m d*, as before, which will intersect all the divisions, converting them into ordinates, 1 *f*, 2 *g*, 3 *h*, &c. to the curve *b d*. The length of these ordinates, from the base-line *e b*, are now to be carefully trans-

ferred to the quadrant of the circle *b d'* of fig. 254, and set off in the circumference thereof: thus the point *b*, in fig. 251, corresponds to the termination *b* of the base-line in fig. 254. The first ordinate, 9 *p*, is to be set off on the quadrant from *b* to *p'*; the second ordinate, 8 *n*, is set off from *b* to *n'*; the third, 7 *m*, from *b* to *m'*; and so on through the entire quadrant of the circle. The radii ***a b***, ***a p'***, ***a n'***, &c. fig. 254, being now drawn, will furnish the successive angles of elevation, with the sole-plane, for each division of the length throughout the quadrant.

661. In applying these to the mould-board, it is to be observed that the first three radii belong to the share, if it is a prolonged mould-board, or the first five if it is truncated. The quadrant, *b d'*, fig. 254, with its radii, being thus completely drawn out at full size upon a board, produce the line ***b a*** to *y*, and on *y* as a centre, with a radius of 7 inches, describe the arc *a t*, and concentric to it the arc *d' u*, from the zero-point *d'*. At an angle of 45° draw *t u* a tangent to the arc *a t*, and the point of intersection of this tangent with the arc *d' u* will fix the extreme point *u* of the mould-board at the height of the line of transit; which point will be 19 inches from the land-side plane *b c*, and 12 inches above the plane of the sole, or base line *y b*. From *d'* lay off divisions of equal parts on the arc *d' u*, each equal to 4½ inches—the diagonal of a square of 3 inches—which completes the lines for the fabrication of the pattern.

662. The next step in the operation is that of *building a block* out of which the pattern is to be shaped. Provide a deal-board of 3½ feet or thereby in length, with a breadth of 10 inches; have it dressed of uniform thickness, and at least one edge and end straight, and right angled, as at *a b c*, fig. 257, forming a basement to the block, *a* being the right angle, and the continuation of the board being hid from view under the superimposed block. Let the edge *a c* of the board be marked off in equal divisions of 3 inches, agreeing exactly with those of the diagram, fig. 252, marking the divisions with letters or numerals corresponding to the radii of the quadrant, *b d'*, fig. 254, the end *a b* of the board corresponding to the radius ***a m'*** of the quadrant, and to the ordinate, 7 *m*, of the figs. 252 or 253. Provide also a suit-stock or bevel of the form represented by *d e f*, fig. 257, the stock *d e* being a straight bar with a head-piece at *e*, fixed at right angles to the stock, and into this the blade *a f* is to be jointed in such a manner that, when the blade and stock are set parallel to each other, they shall just receive the thickness of the basement-board betwixt them—the length of the blade being equal to the breadth of the board. Five or more pieces of well-seasoned, clean, 3-inch Memel or yellow-pine deal are now to be prepared, each about 30 inches in length, and from 6 to 4 inches in breadth. Set the bevel to the angle *b a m'*, fig. 254, and applying it at the end of the board, as in fig. 257, it will point out the position in which the first block *g h* must be placed on the board, in order that it may fill the lines of the pattern. The further end of the block, being set in like manner to fall within the lines, it is to be firmly attached to the board with screw-nails. The second block *i k* is to be joined to the first by the ordinary method of gluing, being set, in the same manner as the first, to fill the lines of the pattern at both ends, and this requires its being set obliquely to the first. The third block *l m*

Fig. 257.



THE BUILDING OF THE BLOCK FOR THE MOULD-BOARD PATTERN.

is set in like manner, and so on with *n o* and *p q*. The setting of the different blocks will be much facilitated by having the ends, *g i l n p*, cut off to the plane of the land-side—that is, to coincide vertically with the land-side edge of the board, and by keeping in view that the terminal line *c q* lies at an angle of 45°.

663. The block being thus prepared, the process of *working it off* is plain and easily performed in this way: Having set the bevel at the angle *b a m′*, fig. 254, which answers to the end *a b* of the block, fig. 257, the bevel is applied as in the figure, and the surplus wood is cut away to a short distance within the end *a b* of the board, until the blade of the bevel lies evenly upon the surface, and the kneed head-piece touching the edge of the board. Set the bevel now at the angle *b a l′*, fig. 254, and applying it at the first division on the edge of the board, fig. 257, cut away the surplus wood with a gouge or other tool, in a line parallel to the end of the board, or at right angles to its edge, until the edge of the blade *a f* lie evenly on the surface, and the head of the stock touch the edge of the board as before. Repeating this operation at each successive division with the bevel, setting it to the corresponding angle up to the vertical or zero-line, and we have a series of leading lines or draughts, each occupying its true position in the surface of the mould-board to the height of the line of transit. By continuing these lines, each in the direction already given it, until they terminate in the breast, or in the upper edge of the pattern, we have a corresponding series of points now determined, in the breast and upper edge, and by removing the surplus wood still remaining in the spaces between the lines, and reducing the surface to coincide with them, we have the finished surface from the neck of the share up to the zero-line.

664. To *complete the after portion of the pattern*, we have to form a temporary bevel with a curved blade, adapted to the small arc *a t*, fig. 254, which blade is prolonged in a tangent *t u* at the angle of 45°. With the guidance of this bevel, its stock being still applied to the board, as in fig. 257, cut away all the wood that occurs to interrupt it behind the zero-line, until it applies everywhere behind that line without obstruction. At the third division, beyond the zero-line, the pattern may be cut off in a right vertical, though this is not imperative, as the mould-board may be made considerably longer, and even a little shorter, without at all affecting its operation. At whatever distance in length its terminal edge may be fixed, that portion of the line of transit which lies between the zero-line and the terminus must leave the original curve *b m d*, fig. 252, at a tangent, and it will reach the terminus as such, or it will gradually fall into a re-entering curve, according as the terminus is fixed nearer to or farther from the zero-line; the terminus of the line of transit being always 19 inches distant from the land-side plane. That portion of the surface which now remains unfinished between the arcs *a t* and *d′ u*, fig. 254, is to be worked off in tangents, applied vertically to the arc *a t*, and terminating in that part of the line of transit that lies between *d′* and *u*. Such portions of the interior cylindrical surface as may have been formed under the application of the temporary bevel to the arc *a t*, are now to be also cut away by a line passing through the junction of the tangents *t a′*, *t b′*, *t u*, with the cylindrical arc *a t*, forming a curved termination in the lower part behind—as seen in fig. 256 from *y* to *z*—which completes the surface as proposed.

665. The *modifications* formerly pointed out, paragraphs 654, 655, 656, may now be made upon the lower and the upper parts of the pattern. The breast-curve and the form of the upper edge will now have assumed their proper curvature; and there only remains to have the whole pattern reduced to its due thicknesses. This, in the fore part, is usually about ½ inch, increasing backward below to

about 1 inch, and the whole becoming gradually thinner towards the top edge, where it may be $\frac{3}{16}$ inch. The perpendicular height behind is usually about 12 inches, and at the fore part 14 inches.

666. *Howard's Patent P. P. Plough.*—Having thus described the best known, and what we consider the most useful of Scotch or swing ploughs, we shall now direct attention to the construction and arrangement of their rival implement, the English or wheel plough, selecting for illustration and description that form so well, and, we may say, favourably known, as "Howard's Patent P. P. Plough." This plough is shown in elevation and plan in Plate III. We have prepared these drawings on the same principle as adopted in the Scotch ploughs, giving a zero-line from which to compute measurements, and to institute comparative observations. The zero-line in the elevation, fig. 1, Plate III., is taken at a part where the width of the mould-board, at a height of $9\frac{1}{2}$ inches from the base-line, is also $9\frac{1}{2}$ inches from the line of the land-side of the body. It should here be noted that, as the mould-board of this plough, unlike that of many others, has a lateral adjustment, the zero-line is liable to be changed in position in proportion to the change of mould-board. This change of position of the zero-line does not, however, affect that of the various parts—and their dimensions—of the plough.

667. The plough may be generally described as being constructed with a beam *a b*, Plate III., and two stilts *c c*. These are forged in one piece, and are bolted to the cast-iron body *d*; this carries the breast or mould-board *e*, the share or sock *f*, and the slade or sole *g*. The coulter *h*, the skim-coulter *i*, the land-side and furrow-wheel *j* and *k*, and the bridle *l*, are fixed to the beam in the manner hereafter to be described. The bridle *l* supports the draught-chain *m m*, the fast extremity of which is attached to the beam near the coulter. The following is a detailed description of the construction of the principal parts.

668. Before describing the details of Howard's plough, it may be interesting to compare the contour of the upper line in relation to the base-line of the best English plough with that of the best Scotch plough—the East-Lothian. On the zero-line, fig. 1, Plate III., the height of Howard's plough above the base line is 1 foot $1\frac{1}{2}$ inch. At a foot distance from the zero-point, towards the stilts, the height is 1 foot $4\frac{3}{4}$ inches; at two feet, it is 1 foot 11 inches; at three feet, 2 feet $6\frac{1}{4}$ inches; at four feet, 2 feet 10 inches, and at five feet at the handle of the stilts also 2 feet 10 inches. Counting one foot from the zero-point towards the beam, the height is 1 foot $3\frac{1}{4}$ inches; at two feet, at the coulter-head, 1 foot 10 inches; at three feet, in front of the skim-coulter, it is 1 foot $10\frac{5}{8}$ inches; at four feet, at the land-wheel, it is 1 foot $10\frac{1}{4}$ inches, and at five feet it is 1 foot $11\frac{1}{4}$ inches. The length of the plough from the zero-point to the end of the stilts is 5 feet $3\frac{1}{2}$ inches, and from the zero-point to the point of the bridle, 5 feet 6 inches, the entire length being 10 feet $9\frac{1}{2}$ inches. The comparison will be most easily made by contrasting Plate III. with Plate I.

669. *The Beam.*—The beam, *a b*, Plate III., is simpler in construction than in the Scotch ploughs, inasmuch as a coulter-box is dispensed with. This allows it to be made quite plain; the only exceptions to this being at the points where two small ears or snags *n o*, fig. 2, are provided, on which to support the two wheels *j* and *k*, and where the end is forked to support the bridle *l*. The exact length of the beam *a b* is 5 feet 6 inches, extending from the zero-line to the outside of the segmental ends at the bridle. In the plan the land-side of the beam is $1\frac{1}{4}$ inches within or toward the furrow-side of the line of sole at *o*; from this point it runs straight to where it is forked for the bridle, this point being coincident with the sole-line. The dimensions of

the beam are as follows: at *o*, 2 inches deep; at the coulter, $2\frac{5}{8}$ inches; and at the joint of the bridle, $2\frac{1}{8}$ inches deep; the thickness at these points being the same—namely, $\frac{7}{8}$ of an inch.

670. *The Stilts.*—These, *c c*, fig. 2, Plate III., at their junction at the zero-line with the beam, open out quickly to a width of 4 inches; this affords space to place a tin box *p* with hinged cover, useful to hold any extra materials required during the working of the plough. From this point the stilts gradually widen to the extreme ends, where the distance from centre to centre is 2 feet 1 inch, the length of the stilts from the zero-line being 5 feet $3\frac{1}{2}$ inches: of this distance $7\frac{1}{4}$ inches are taken up by the wooden handles *q r*, through which the reduced extremities of the stilts pass. Unlike the East-Lothian plough in Plate I., where the little stilt or right-hand one alone branches out, the width between the two stilts of Howard's plough increases equally on both sides of the centre-line of the beam. They are braced and connected together by three stretchers *s t u*, and one bow *v v*. The dimensions of the stilts are as follows: at bottom, where they join the beam at zero-line, $1\frac{1}{8}$ inches deep and $\frac{5}{8}$ inch thick, tapering off to where they join the wooden handles, to $1\frac{1}{2}$ inches deep, and $\frac{3}{8}$ of an inch thick.

671. *The Body* is shown in detail in figs. 258 and 259, of which the fig. 258

Fig. 258.

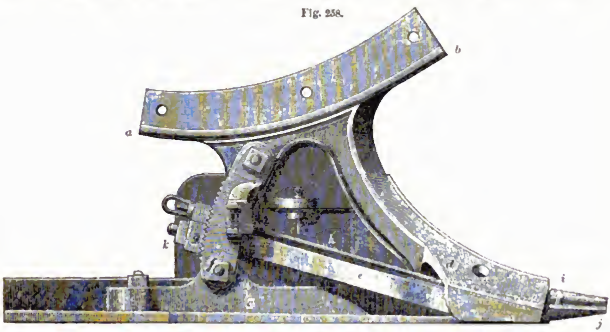


Fig. 259.

PLAN AND ELEVATION OF BODY OF HOWARD'S PLOUGH—SCALE, 1 INCH TO THE FOOT.

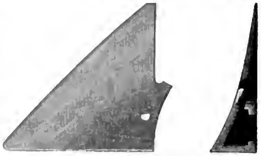
is an elevation, and fig. 259 a plan, partly in section. The upper edge has a cheek *a b*, fig. 258, to receive the beam, which is secured by three bolts, as shown by the bolt-holes in the cut. At bottom the body extends in front of the zero-line 2 feet, and 1 inch behind it. The *sole* or *slade*, *c*, is fixed to the under-side of the body by two bolts, one of which is shown by dotted lines in fig. 258; it covers, as usual, a portion of the land-side of the body. The depth of the sole is 2 inches; this increases, however, to $3\frac{1}{8}$ inches near the front end, decreasing again, along with the body, to 2½ inches at the front, as shown by the dotted lines in fig. 258. The length of the sole is greater than that of the body, being 2 feet 7 inches. The thickness of the lower flange at the front end is ⅜ of an inch, and at the back ¾ of an inch. The front of the body at *d*, for about 7 inches in length, is made 2¼ to 2¾ inches broad; the upper side being twisted to fit the curve of the mould-board, and the lower side hollowed. This hollow recess receives and supports the bar *e*. This bar, which carries the share, is of wrought-iron, 1¼ inches deep and ⅝ of an inch thick on the body. It is provided with a tapered point, grooved in the upper side, which fits into the socket of the share, the construction of which will be hereafter described. Immediately behind this tapered point, the bar *e* is provided with small curved projections, one on each side; these fit into and rest in corresponding recesses made in the hollow point of the part *d* of the body. These afford joints or fulcra in which the bar *e* is supported, and by which a vertical adjustment, through a small space, can be given to it. The other end of the bar *e* is furnished with a screwed bolt, which passes through a slot formed by a recess in the head, and a small bracket *f* bolted on in front. The back edges of the head at this point and of the bracket *f* are provided with a number of transverse notches, or angular indentations; these fit into similar notches on the edge of a block or washer *g*. The screwed end of the bar *e* is passed through this washer *g*, and the nut *k* tightens against it. These notches tend to keep the washer *g* firmly fixed in any desired position when the nut *m* is screwed up. Immediately above and parallel with the bar *e*, a small rod *h* is placed; the upper extremity of this is formed into a screw-bolt, and passes through the washer *g*, and is provided with a nut, as shown in fig. 258. The lower extremity is turned up at right angles, as shown at *i* in fig. 258, and *m* in 259, and rests in the groove *j*, fig. 258, and *l* of the tapered point of the bar *e*, fig. 259. The office of this rod *h*, fig. 259, is to fix the share, the point *i* passing through a hole made on the top of the share. As the rod *h* is tightened up by the nut at its upper end, it draws the share tightly to its seat on the bar *e*. The share may be raised at the point or lowered as desired, by the vertical adjustment of the bar *e*, formerly described. The land-side of the body is only partially covered in by a plate *o*, fig. 259, 6 inches deep, supported in a simple manner by two small hooks at bottom, which catch on the upper edge of the sole *c*, fig. 258, and are secured at top by a pin passed through an eye formed in the inside of the body, and another in the side-plate.

672. *The Mould-board*, *e*, Plate III.—This is made either of cast-iron or of steel-plate. The extreme length is 3 feet 5 inches, and its greatest height 1 foot 1 inch. Unlike the mould-board of the Scotch ploughs, it does not cover in the whole of the front edge of body up to the beam; but, as is commonly done in English ploughs, it is curved on the front edge by a line approximating in outline to that described by the furrow-slice in its passage along the face of the mould-board, as in fig. 5, Plate II. The mould-board is fixed to the head by a bolt at its point; by a second bolt *w*, fig. 2, Plate III., one end of which is connected with a small angled bracket near the middle, and the other with the bracket *f*, fig. 258, on the body; a third bolt *x*, fig. 2, Plate III., near the back end, connecting it with a wrought-iron stay supported by the right-hand stilt. The bolt which attaches the point of the mould-board to the head, serves as a joint on which the mould-board turns, when its width behind is required to be altered. To allow of this movement the other bolts *w x* have adjustments in their supports. The lower edge of the mould-board is furnished with a cast-iron strap called a *rest*, 1 foot 3 inches in length. As the principal wear takes place

at this part, it is attached by two bolts, this admitting of its removal when necessary.

673. *The Sock or Share, f,* Plate III., is made either of cast or wrought iron. Cast-iron, however, is most frequently used; and being run into a metal-mould or chill, the sock is rendered extremely hard. In fig. 260 we give a plan, and in fig. 261 an end view of the cast-iron share. Its length and extreme breadth are equal, being $8\frac{3}{4}$ inches, its thickness varying from $\frac{3}{8}$ of an inch at the land-side to $\frac{1}{8}$ of an inch at the cutting edge. The under-side is provided with a box or socket to fit the point *j* of the bar *e*, fig. 258.

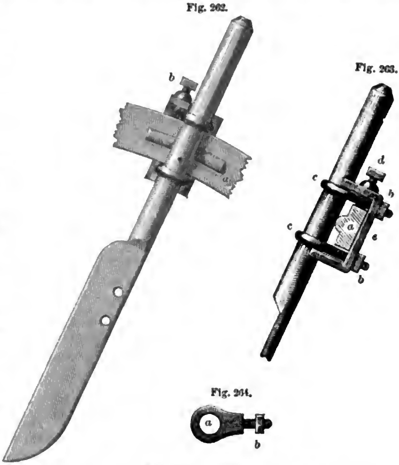
Fig. 260. Fig. 261.



DETAILS OF SOCK OF HOWARD'S PLOUGH—SCALE, 1 INCH EQUAL TO 1 FOOT.

674. *The Coulter, h,* Plate III.—Of the coulter we give in fig. 262 an elevation, and in figs. 263 and 264 details of the fixtures. The cutting part of the coulter is 1 foot 3 inches in length, in the breadth $2\frac{1}{2}$ inches; it is $\frac{5}{8}$ of an inch thick at the back, and is thinned away to the front in a cutting edge. It is fixed to the beam by a rounded stem, the length of which is 1 foot 2 inches, and its diameter $1\frac{3}{8}$ or $1\frac{1}{2}$ inches. Unlike the coulters of the majority of other ploughs, this one is not fixed rigidly to any particular angle with the sole-line, but can be varied in position within a range of 5 inches, by moving its supports along the beam. To the land-side of the beam, at the point where the coulter is attached, a half-round rib *a*, figs. 262, 263, $5\frac{1}{2}$ inches long, is fixed. The stem of the coulter is driven forcibly in contact with this rib, which forms the fulcrum on which the coulter moves laterally when required, by two eye-bolts *c c*, fig. 263, one of which is shown detached in fig. 264, *a* being the aperture through which the coulter stem passes, *b* the nut. One of those eye-bolts is placed above and the other below the beam, their screwed ends passing through a plate *e*, fig. 263, in the opposite side of the beam; which plate is provided with knees above and below, and is notched to embrace the coulter. When this plate is tightened up by the nuts *b b*, the parts are all firmly bound together. The office of the plate is to steady the coulter, and prevent its lower point being forced back when the implement is at work. Near the front edge of the upper knee of the plate *e*, a screw *d* passes through it, and, resting on the

Fig. 262. Fig. 263. Fig. 264.



DETAILS OF COULTER OF HOWARD'S PLOUGH—SCALE, 1 INCH TO THE FOOT.

beam, keeps the coulter firm. Perfect adjustment of the cutting edge of the coulter to the furrow-slice is attained by the round stem with which it is provided.

675. *The Drag-chain*, *y*, fig. 1, Plate III.—To the back edge of the blade of the coulter a light chain, termed the drag-chain, is attached. Its length is 2 feet 3 inches, and it is provided with a small weight or roller at its outer extremity. It lies across the furrow-slice while it is being turned over, and its office is to drag off all grass, stubble, &c. from the edge of the slice, and to bury them underneath, thus preventing all vegetation in the hollows. This arrangement finishes the work performed by the plough in such a way as to present to the eye nothing but the freshly-cut surfaces.

676. *The Skim-coulter*, *i*, Plate III.—The drag-chain just described acts most properly in conjunction with the skim-coulter *i*. This skim-coulter is in fact a miniature plough, set at a short distance in front of the principal coulter, and its office is to pare off the top of the furrow-slice before it is turned over, when lea or stubble is ploughing. By this arrangement the grass and stubble are cut away, to prevent them being seen when the ploughing is completed, and are buried by the action of the drag-chain, as already explained. The skim-coulter consists of a small mould-board and share, supported by a stem $1\frac{3}{4}$ inches broad and $\frac{3}{4}$ inch thick. It is attached to the land-side of the beam by a wrought-iron strap *z*, having screwed tails, which pass through a plate on the opposite side of the beam. The lower tail has a screw which jams against the beam, and keeps the skim-coulter steady. The skim-coulter is not a feature peculiar to Howard's plough alone, but has long been in use in other forms of English implements.

677. *The Land-wheel.*—The land-wheel, *j*, Plate III., for regulating the depth of the furrow-slice, is attached to the beam in advance of the skim-coulter. The diameter of the wheel, which is of cast-iron, is 13 inches, the breadth of rim being $\frac{7}{8}$ of an inch. Its axle has its bearing in a light stem *o*, 1 foot 7 inches long, and $\frac{7}{8}$ of an inch square, the upper end of which passes through the square eye of an eye-bolt attached to the land-side of the beam. The office of this eye-bolt is to draw the stem against two notched ears or snags projecting from the upper and lower edges of the beam, one of which is shown at *n*, fig. 2, fixing the wheel at any required height. To keep the axle of the wheel clear of earth, weeds, &c., both ends are protected by light cast-iron shields or covers; the periphery of the wheel is kept clear of adhering soil by means of a light scraper which has an attachment at the top of the stem *o*.

678. *The Furrow-wheel*, *k*, Plate III., which regulates the breadth of the furrow-slice, is placed about 8 inches in advance of the land-wheel, and is attached by a vertical stem *o*, fig. 1, to the beam in a similar manner. Unlike the land-wheel, which, as it regulates depth, has only a vertical adjustment, the furrow-wheel has to regulate breadth, and has therefore two adjustments, vertical and horizontal. To provide for the horizontal adjustment, the axle has a square tail *p*, fig. 2, which slides longitudinally in, and is secured by an eye-bolt attached to the foot of the vertical stem. The diameter of the wheel is 1 foot 9 inches, the breadth being $\frac{3}{4}$ of an inch. A scraper for the rim, and covers for the ends of the axles, are provided for this as for the land-wheel.

679. *Chain-rod*, *m m*, fig. 1, Plate III.—The plough is drawn by a chain-rod $\frac{1}{2}$ an inch in diameter, attached by a shackle to the beam near the body. A vertical bar, 9 inches long, 1 inch broad, and $\frac{5}{8}$ of an inch thick, is provided with an eye at its lower end, through which the chain-rod passes. This bar is fixed near the point of the beam, and is adjusted to any required height by an eye-bolt and nut *l*, fig. 1, in front of the bridle.

680. *The Bridle, l l,* fig. 2, Plate III.—The bridle consists of a light doubled iron strap, about 12 inches long. The links, in thickness ¼ of an inch, embrace the beam above and below, and turn on a vertical pin in the beam. The end of the beam, from this joint-pin forward, is reduced in depth both above and below to receive the bridle; the two light segmental plates are riveted to the forked ends. These plates are pierced with a number of holes, and as a hole is made to correspond in the bridle, a light pin dropped through all keeps the bridle and the drawing chain in any required position nearer to or farther from the land.

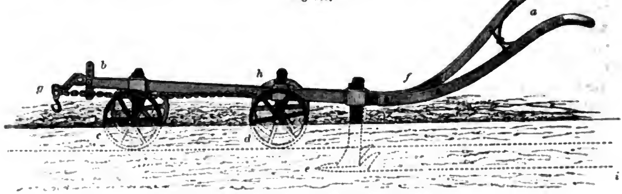
681. In Plate II. we give analytical sections of the mould-board of Howard's plough, fig. 5 being a side-elevation, and fig. 6 a fore-end view. Fig 5 is a geometrical elevation in a plane parallel to the land-side of the mould-board, *l m* being the base line. The perpendicular lines of division commencing at *o o*, the zero, and extending right and left, are the lines of section corresponding to those of the East-Lothian plough mould-board, fig. 1, Plate II., and described in par. 639. The line of transit of the furrow-slice is represented by the dotted line *x y z*. Fig. 6 is a front view of the elevation corresponding to fig. 5; *m i* is the base line of the plough, *g i* is the land-side of the plane in a vertical position; *i* is the place of the point of the share, and *k h* the line of junction between the neck of the share and the mould-board; the remaining lines beyond *k h* exhibit the outlines of all the sections taken by the parallel ruler, fig. 250, in reference to the lines in fig. 5. Thus *o o g g* is the entire body of the plough forward in the plane of the zero line, *o y o* being the outline of the mould-board at this section, and *y* the zero point; *a a g g* the first section forwards from the zero line, and so of all the other lines to *g g*. In like manner *o o* 11 is the first section backwards from the zero line, and so of all the other lines to 5, 5. The entire series of lines backward and forward from zero *o o* form a series of profiles of the mould-board, supposing it to be cut vertically by planes at right angles on the land-side of the plough. The dotted lines *i y* represent the passage of the furrow-slice from its first motion from the fulcrum *l* to its perpendicular position in *l y n m*; and *m s z r* represent a transverse section of the same furrow-slice in its progress to be finally deposited by the mould-board. The line of transit of the furrow-slice is the dotted line *x y z*, corresponding to the dotted line *x y z* in fig. 5.

682. *Trench and Subsoil Ploughs.*—Since the general draining of the soil received the assent of the agricultural community, deep ploughing has presented itself to the attention of the farmer in a favourable light. Various forms of implements have been devised to descend as far into the soil as to stir the subsoil effectually, and they have obtained the name of *subsoil* and *trench* ploughs, according as they affect the subsoil. The subsoil-ploughs stir the subsoil lying under the active soil, without affecting their relative positions, whereas the trench-ploughs bring up more or less of the subsoil over the active soil of the surface.

683. In the subsoil ploughs formerly in use it is more than probable that the furrow-slice was uneven, both in the direction of the length of the furrow and in the relation which the sole of one furrow bears to that of another. It is evident that, if the furrow-sole in its length is undulating, and that one furrow-sole, in its breadth, is higher and lower than the contiguous ones, the plane of the furrow-sole across the ridges will be so irregular that the water, descending the inclination of the ground, will be interrupted in its progress to the drains. To give the plane of the sole a uniform depth, it is only necessary to introduce wheels upon the beam of the subsoil ploughs, which will cause its furrow-sole

to preserve a parallelism with the furrow-sole left by the preceding common plough. This obvious means of steadying the action of the subsoil plough was introduced into a subsoil-plough invented by Mr Read, which is represented in fig. 265 as improved by Mr Slight, and where the alteration converted the

Fig. 265.



* READ'S SUBSOIL PLOUGH, AS IMPROVED BY MR SLIGHT.

plough into the form of a grubber. The implement consists of a malleable-iron beam *b f*, to which at one end, *f*, are attached two handles *a*. To the other end is welded an iron slot, *b*, placed perpendicularly, and punched with holes, into any one of which the bridle *g* may be fastened by means of a bolt and cotrel. The bridle *g* is winged to the land-side, in order that the two or four horses which are employed to draw the plough may walk upon the hard ground; and to sustain their lateral draught, one end of a chain is fixed to the extremity of the wing of the bridle carrying the draught-hook, and the other is attached to the beam at *h*. The wheels *d* and *c*, coupled in pairs on axles, are attached to shanks which pass through boxes in the beam, the same as the coulter-head in the common plough. The shank of the double-feathered share *e* is affixed in the same manner as the wheels to the beam. The dotted line below the wheels *c d* shows the line of the furrow-sole made by the plough which preceded this implement in the work of subsoiling; and it should never be less than 8 or 9 inches below the surface of the ground. The dotted line *e i* behind the share *e* shows its line of motion, and the distance between these lines is regulated by the depth given to the axles of the wheels *c* and *d* below the beam *b f*, which may vary from 6 to 9 inches. The beam resting on the two pairs of wheels *c* and *d*, and the ploughman in the bottom of the furrow made by the preceding plough, with a hold of the handles *a*, afford so steady a motion to the share *e* that it may be regarded as uniform, and its work will be much better performed than by the older subsoil-ploughs.

684. In 1849 the Marquess of Tweeddale effected an important improvement on Read's subsoil-plough, that, while its useful form was retained, its action was altered from a simple subsoiler, which merely stirs the subsoil and leaves it where it found it, to a trenching subsoiler, which effects a mixture of the subsoil with a portion of the surface-soil. The implement is represented in Plate V., by which it will be seen that the beam and stilts of the implement are preserved exactly according to Read's form, as improved by Mr Slight, and the important alteration is exhibited in the share and its appendages. These consist of the share *f g*, with its tail-board or elevator *h h*, attached to a shank *e e* passing through a mortise *d* in the beam *a b*. The shank *e e* is a bar of the best scrap-iron, and at bottom is forged with a club end, fitted to receive the attachment of the body of the share *f g* by welding or by riveting; and to the hind part of the share the tail-board *h h* is strongly fixed by bolts.

685. The Tweeddale subsoil trench-plough having a share 14 inches in width, a common plough is inadequate to go before it, to open a sufficient furrow for its passage. Lord Tweeddale supplied the want by the true philosophical mode of induction, with numerous and untiring experiments on a large scale. By these he constructed a plough having its mould-board formed upon a new system of lines and of dimensions that render the plough capable of taking a furrow-slice 12 inches wide and 13 inches deep in the most effective manner. This plough, named the "Tweeddale Plough," leaves a clean and flat-soled furrow; but the furrow-slice taken by it, in place of being turned over in an entire form, in the manner effected by our *fine*-working ploughs, is only so far turned, and at the same time broken up, as serves to present the soil in the best possible state to the ameliorating effects of atmospheric influences. In this respect the plough seems to stand unrivalled; and since the extinction of the old Scottish wooden plough, no implement has approached the point to which this has attained, for enlarging the extent of surface exposed to the atmosphere.

686. *The Tweeddale Plough.*—The Tweeddale plough is represented in elevation in fig. 1, and in plan, fig. 2, Plate IV. The principal details of construction are given in figs. 266, 267, and 268, these being drawn to a scale of 1

Fig. 266.

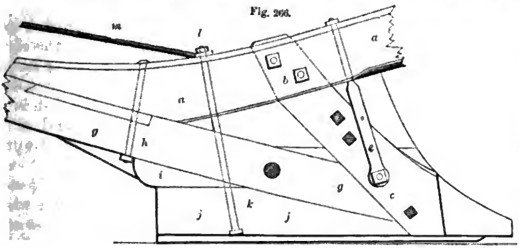
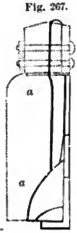


Fig. 267.



DETAILS OF THE BODY OF THE TWEEDDALE PLOUGH—SCALE, 1 INCH TO THE FOOT.

inch to the foot. Fig. 266 is an elevation of the body, with the mould-board and right-hand stilt removed; fig. 267 a front elevation of the cast-iron head, &c.; and fig. 268 an elevation of the land-side of the body. The material of which the beam, stilts, and part of the body are constructed, is either ash or oak, selected so that the natural curve of the wood will coincide as nearly as possible with the finished form of the parts. Wood was preferred to iron, partly on account of its stiffness, but chiefly on account of its elasticity, recovering its form quickly even after a severe strain. The head, sole, side-plates, and mould-board, are of cast-iron; the sock, coulter, bridle, and some minor parts, of wrought-iron.

687. *The beam, a a,* fig. 266, supports the framework of the body as follows: The head *b* is provided with a tenon at its upper extremities, which passes through a mortise made in the beam, and is secured thereto by the two bolts as shown. These bolts serve also to strengthen the beam, and prevent its splitting when subjected to any severe twisting strain. The connection of the head to the beam is further secured by an iron strap *c*, bolted on to the face of the head at *e*, and passing upwards through the beam in front of the mortise, a nut on the upper edge of the beam being used to tighten the strap as required. To support and fix the front part of the mould-board, a blocking

of wood, shown by the dotted lines *a a* in fig. 267, is secured to the face or mould-board side of the head by strong wooden pins passing through holes in the cast-iron head. To enable the stilts to be easily fitted to them, this blocking and the hinder edge of the head are flush with one another.

688. *The left-hand stilt*, *g g*, fig. 266, is connected to the beam by a shallow mortise-and-tenon joint, and secured by a bolt *h*. The line of the land-side of the beam and stilt is made slightly to the right of the line of the sole, as shown in fig. 2, Plate IV. Packing-pieces, *i* and *j j*, fig. 266, of the same thickness of the stilt, are nailed to its under-side, and to receive the sole-shoe, are finished level with the under-side of the head *b*. To strengthen the framework of the body, a bolt, shown in dotted lines at *k*, passes upwards from the lower packing *j j*, and is tightened by a nut at top *l*; the upper end of this bolt passing through the eye of the stay-rod *m*, which connects the upper part of the stilt and beam, as shown by *e* of fig. 1, Plate IV. This arrangement adds materially to the security of the stilt.

689. *The right-hand stilt*, *d f*, fig. 2, Plate IV., is fixed to the bottom of the left-hand stilt, and to the packing-piece *j j*, fig. 266, attached to the head, by bevelling off its inner side and end, the two stilts being secured together partly by nailing, and partly by a strong wooden pin passed through both near the bottom. Their upper extremities near the handles are connected together by a single stretcher of iron, as shown in fig. 2, Plate IV. To the face of the right-hand stilt, wood-blockings *f*—shown in the plan, fig. 2, Plate IV.—are nailed; these assist in supporting and fixing the mould-board. After the frame-work is put together, to enable the mould-board to lie perfectly solid and in its exact position, with the front edge resting firmly on the enlarged end of the head, these blocking-pieces, and the packing-piece *j j*, fig. 266, attached to the head, are cut away, till the exact adjustment is obtained.

690. To enable the beam to resist the great strains to which it is subjected, a plate of iron is secured by nails driven in at short intervals along the whole length of its under-side. The cross section of this plate being curved, so as to fit the rounded lower edge of the beam, considerable stiffness is attained with little weight of material. To secure this plate at the end of the beam, a stout rivet passes through both; this also prevents the splitting of the beam at this point, a tendency to splitting being created by the oblique action of the bridle.

691. *The mould-board*, *j j*, Plate IV., is fixed near its front edge to the packing-piece *j j*, fig. 266, attached to the head, by three nails driven through countersunk holes made in the mould-board, and through coincident holes in the packing-piece. A little behind the centre of the mould-board a countersunk bolt-hole is provided; through this, and through the right-hand stilt and its blockings *f* a bolt passes, and is tightened up by a nut inside the stilt. This second attachment of the mould-board serves to stiffen the framework by connecting, through the intervention of the mould-board, the right-hand stilt with the head.

692. *The coulter*, *i*, fig. 1, Plate IV., is fixed by wedges in a mortise made in the beam, and is supported below by the strengthening plate which passes along its under-side, and above by another plate of iron, in which the aperture is made slightly longer than the head of the coulter. To give strength and depth to this plate to hold the wedges, the hole is thickened round its edges.

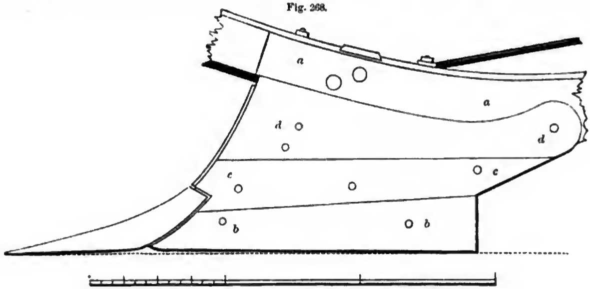
693. The *sock* or *share*, *e*, Plate IV., is similar in construction to that of the East-Lothian plough, illustrated in figs. 227 to 231 inclusive. To meet

the greater strain to which it is subjected, it is, however, made larger and stronger.

694. The *bridle*, *k k*, fig. 2, Plate IV., is also similar to that of the East-Lothian plough, figs. 238 and 239, but stronger, to resist the greater strain to which it is subjected. The width between the sides is also greater, the beam being of wood in place of iron, and consequently thicker. It is secured by two bolts passing through the beam, one of which forms a joint or centre on which the bridle turns when the line of draught is to be raised or lowered. The other bolt passes through one of the pairs of holes in the segmental ends of the bridle, and secures it in the required position. To prevent the chafing of the wood of the beam by the action of these bolts, small iron plates are sunk flush with the surface into the beam in each side near the holes.

695. *The land-side* of the body, fig. 268, up to the lower edge of the beam

Fig. 268.



LAND-SIDE OF THE BODY OF THE TWEEDDALE PLOUGH—SCALE, 1 INCH TO THE FOOT.

a a, is covered in by the sole-shoe *b b*, and two cast-iron plates *c c* and *d d*, fixed by countersunk nails to the left-hand stilt, and to the wooden pins which pass through the head. Above these a thin sheet of iron is nailed on to protect the beam at *a a*.

696. The general dimensions of the plough are given in Plate IV., the figures of which are constructed on the same principle as those of the other ploughs we have selected for illustration. The perpendicular lines, and the dimensions marked at each, indicate the height to the upper side of the beam and stilt at every 12 inches on either side of the zero-line. This line is taken at the point where the width of the mould-board is 14 inches from the land-side.

697. The beam extends forwards from the zero-line 5 feet 2½ inches from *a* to *b*, and backward from *a* to *c* 1 foot 7½ inches, giving a total length of 6 feet 10¼ inches. The stilts extend backwards from the zero-line *a* to *d* 6 feet 5½ inches, so that the length from the end of the stilts *d* to the front of the beam at *b* is 11 feet 8¼ inches. The obliquity of the line of the beam and stilt to the land-side of the sole amounts to 2 inches at the point of the beam at *b* to the right or furrow side of the sole-line, and at the extreme end of the stilt at *d* it amounts to the left of the furrow-side of the line to 1¼ inch.

698. The depth of the beam at the point where the head, fig. 268, is inserted at *a* is 5 inches, the breadth or thickness being 4 inches; these dimensions gradually tapering to the point at *b*, fig. 1, Plate IV., to 3½ inches deep and 3 inches thick. The under-side is rounded a little, the corners of the upper side being bevelled or splayed off on each side of the centre line.

699. The depth of the left-hand stilt at its insertion in the body is 4 inches, the thickness being 3 inches, those at the right-hand stilt at the same point being $3\frac{3}{4}$ inches by $2\frac{1}{2}$ inches. Both of the stilts taper off to $1\frac{3}{4}$ inches deep and $1\frac{1}{4}$ inches thick at the upper ends *d d*, fig. 2, Plate IV. They are each dressed off to an oval section behind the body, not pointed above.

700. The point *e*, figs. 1 and 2, Plate IV., of the sock is 3 feet in front of the zero-line, and the back end *f* of the sole-shoe 6 inches behind, making the total length of the sole 3 feet 6 inches.

701. The lower part of the coulter *i* is 3 inches broad and $\frac{3}{4}$ of an inch thick at the back, and thinned off to the front edge. Where the coulter is fixed to the beam, the upper part is $2\frac{1}{4}$ inches broad and $\frac{3}{4}$ of an inch thick.

702. The front edge *g* of the mould-board under the beam is 1 foot $2\frac{1}{4}$ inches in front of the zero-line, and at bottom 1 foot $8\frac{1}{2}$ inches. The upper edge *h* extends backwards from the zero-line 1 foot, the height at this point being 1 foot $5\frac{1}{2}$ inches. The width from the land-side is 1 foot $6\frac{1}{4}$ inches, increasing a little below the top edge to 1 foot $8\frac{1}{2}$ inches.

703. The analytical section of the mould-board of this plough is given in figs. 7 and 8, Plate II. Fig. 7 is a geometrical elevation in a plane parallel to the land-side of the mould-board, *l m* being the base-line. The perpendicular lines of division, commencing from the lines *o o* the zero, and extending right and left, are the lines of section corresponding to those already described in the East-Lothian plough at figs. 1 and 2 of Plate II. and par. 639. Fig. 8 is a front view of the elevation of the Tweeddale plough corresponding to fig. 7; *q l* is the base-line of the plough, *f l* is the land-side plane in a vertical position; *b* is the place of the point of the share, and *i i* the line of junction between the neck of the share and the mould-board; the remaining lines beyond *i i* exhibit the outline of all the sections taken by the parallel ruler, fig. 250, in reference to the lines in fig. 7. Thus, *o o f l* is the section of the entire body of the plough forwards in the plane of the zero-line, *o y o* being the outline of the mould-board at this section, and *y* the zero-point; *a a f l* the first section forwards from the zero-line, and so of all the other lines to *i i*. In like manner *o o* 11 is the first section backwards from the zero, and so of the other lines to 3, 3. The entire series of lines backward and forward, from zero *o o*, form a series of profiles of the mould-board, supposing it is to be cut vertically by planes at right angles to the land-side of the plough. The dotted line *l y* represents the passage of the furrow-slice, from its first motion upon the fulcrum *h* to its perpendicular position in *r y j q*; and *q k z m* represents a transverse section of the same furrow-slice as finally deposited by the mould-board. The dotted line *x y z* is the line of transit of the furrow-slice corresponding to the dotted line *x y z* in fig. 7.

704. On comparing the action of the mould-board of the rectangular-furrow plough, the East-Lothian, the high-crested furrow plough, the Lanarkshire, Howard's English, and the Tweeddale plough, upon the last position of the furrow-slice, it will be observed that the mould-board of the East-Lothian, from 3 to 2, fig. 2, Plate II., presses upon almost the entire side *z s* of the furrow-slice *k s z n*, thereby compressing the soil, while the furrow-slice is laid over at an angle of 45°. The mould-board *z* 2, 1 of the Lanarkshire plough, fig. 4, presses still more upon the side *z t* of the furrow-slice *k t z r*, which is only laid over at an angle of 40°, thereby flattening and compressing the slice at the same time. The mould-board 5, *o*, of Howard's plough, fig. 6, merely presses on the angle *s* of the furrow-slice *m s z r*, which is laid over at about the angle of 44°, thereby leaving the furrow-slice a little compressed on the lower edge. The mould-board of the Tweeddale plough 3, 3, fig. 8, just rubs off the projecting

angle *n p k* of the furrow-slice *q k z m*, which is laid over at an angle of 45°, thereby compressing the furrow-slice scarcely at all.

705. The extreme length of the mould-board of the East-Lothian plough, fig. 1, Plate II., is 1 foot 10 inches; that of the Lanarkshire plough, 2 feet 2½ inches; that of Howard's English P. P. plough, 3 feet 5¾ inches; and that of the Tweeddale plough, 2 feet 8 inches.

706. The measurements of the height of the upper line of the Tweeddale plough, fig. 1, Plate IV., above the base-line, are as follow: At the zero-line it is 1 foot 4⅝ inches; at 1 foot forward from the zero-line it is 1 foot 7¾ inches; at 2 feet, at the coulter-box, it is 1 foot 11 inches; at 3 feet it is 1 foot 11¼ inches; at 4 feet, at the segmental end of the bridle, it is 1 foot 9¼ inches; and at 5 feet, near the joint of the beam, it is 1 foot 7 inches. At 1 foot backward from the zero-line, the height is 1 foot 3¾ inches; at 2 feet it is 1 foot 4¼ inches; at 3 feet it is 1 foot 8¾ inches; at 4 feet it is 2 feet 1¾ inches; at 5 feet it is 2 feet 7¼ inches; and at 6 feet, near the end of the stilts, it is 3 feet ½ inch.

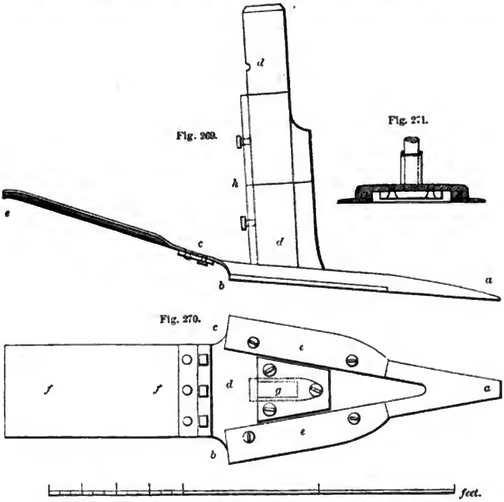
707. *The Tweeddale Subsoil-Trench-Plough.*—We now come to describe the Tweeddale subsoil-trench-plough, the elevation of which we give in fig. 1, Plate V., fig. 2 being a plan. The plough is constructed entirely of iron—with the exception of the handles—having a straight beam *a b* and a pair of stilts *c c*. The sock *f g*, which is supported by the stem *e e*, in a mortise *d* near the back end of the beam, consists of a broad triangular plate *f f g*, fig. 2, with steel wings or cutters *f f* at the side. A plate *h h*, which is called the tail-board or elevator, is fixed to the back of the sock, and slopes upward. A bridle *i i* is provided at the end of the beam to allow of the adjustment of the line of draught towards the right or left, the vertical adjustment being obtained by the wheels *j j* attached to the beam a short distance from the extremity. The depth to which the sock penetrates is regulated by raising or lowering these wheels.

708. The following are the dimensions of the principal parts of the plough: The extreme length of the beam over all is 7 feet 4 inches; the length from the centre of the draught-bolt *r* to the front of the coulter or sock stem *e e* being 5 feet 2 inches. At the coulter-mortise *d*, fig. 1, where the thickness is 1½ inches, the depth of the beam is 4 inches, tapering gradually to the extremity to 2½ inches, the thickness at this point being ¾ of an inch. To admit of the coulter-mortise, the part of the beam surrounding it suddenly swells out to a thickness of 3 inches, and a depth of 5 inches, the dimensions of the mortise being 4¼ by 1¼ inches. Immediately behind this part the beam is reduced, and tapers to the back extremity, where the depth is 2 inches and the thickness ¾ of an inch.

709. The stilts *c c*, fig. 2, are attached to the beam behind the coulter-mortise by two bolts, the distance between which is 11 inches. The bolt near the end of the beam passes through two tubes or distance-pieces, which fill up the spaces *l l* between the beam and the stilts. The stilts behind these distance-pieces are connected and stiffened by two stretchers *m* and *n*, and a bow *o o*, the ends being finished off with wooden handles *p p* in the usual manner. Not including the handles, the extreme length of the stilts in a horizontal direction is 5 feet, the extreme length from the draught-bolt *r* over the wooden handles being 11 feet 8 inches. At the lower end of the stilts the thickness of the iron is ¾ of an inch, the depth being 2¼ inches, these dimensions decreasing at the point near the handle-sockets to a depth of 1¾ inches, and a thickness of ½ an inch. From the under-side of the sole the height of the front of the beam is 1 foot 2 inches,

at the point above the coulter-mortise it is 1 foot, and to the top of the handles 3 feet.

710. In fig. 269 we give an elevation; in fig. 270 a plan of the under-side; and in fig. 271 a cross section at the widest part of the sock of the plough. The



DETAILS OF THE SOCK OF THE TWEEDDALE SUBSOIL-TRENCH-PLOUGH.

sock is made of a plate ½ an inch thick, 1½ inches broad at the point *a*, fig. 270, 12 inches broad at *b c*, and reduced suddenly at the point *d* to 8 inches. The length from *a* to *b* or *c* is 1 foot 10 inches or 2 feet. Along the under-side of the edges a rib is forged, and steeled below to the length of 10 or 12 inches from the point, the remainder of the length being checked to receive the movable steel cutters *e e*. These are 3 inches broad and ½ an inch thick, and are secured to the edges of the sock by rivets as shown. The total depth of the body thus formed is 1¾ inches, but it is thinned down at the point to ¼ of an inch.

711. The tail-board or elevator *f*, fig. 270, extends behind *b* and *c* 1 foot 8 inches; it is provided at its lower extremity with a plate riveted on its under-side, this plate being connected to the back end of the sock by three screws, as shown in the figure. The angle at which the tail-board is fixed is such as to make the upper extremity *e* 8 inches above the level of the point of the sock; the sole of the sock, as will be observed from fig. 269, being also inclined upwards 1½ inches from *a* to *b*. The length of the tail-board *f f*, fig. 270, is 1 foot 4 inches, its breadth 8 inches, and its thickness ¼ of an inch; it is hollowed to the extent of ½ an inch on the upper-side.

712. The stem, *d d*, fig. 269, of the sock is 1 foot 11 inches long above the sock, 3½ inches broad, and 1¼ inches thick. The lower end is passed through a mortise in the sock-plate, and the broad end of *d d*, fig. 269, secured to the under-side of the plate by three countersunk screws, as shown at *g* in fig. 270.

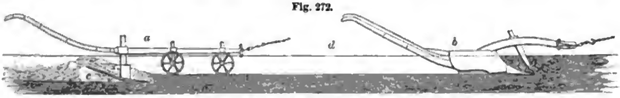
The stem is secured in the mortise of the beam by a wedge in front, and by a pin behind, as at *e*, fig. 1, Plate V. This pin is driven into a circular check, one half of which is formed in the mortise of the beam, and the other in the stem of the sock; by this arrangement the sock is kept firmly in its place. The stem between the beam and the sock is covered by two cast-iron boxes or shields, fixed by screw-bolts as at *h*. To facilitate the passage of these shields through the soil, they are pointed in front.

713. The wheels *j j*, Plate V., for regulating the depth to which the sock penetrates, are attached to the beam *a b* at a distance of about 1 foot 9 inches behind the draught-bolt *r* by means of a simple buckle and pinching-screws, the screws drawing the stem of the wheels against the beam. The diameter of the wheels is 1 foot 4 inches, and they are mounted, 6 inches apart, fig. 2, on axles attached to the stems; the diameter of the axles where they pass through the wheel being 1 inch, the thickness of the stems being $\frac{5}{8}$ of an inch, and the breadth $2\frac{1}{4}$ inches.

714. The bridle, *i i*, Plate V., is supported by the draught-bolt *r* at the point of the beam, and is simply a plate 1 foot 2 inches long, having ears at one end, by which the connection with the beam is secured. A number of holes are provided for attaching a shackle and draught-hook. The projection of the bridle is principally on the land-side of the beam, and it is stayed at its outer end by a chain-bar *k k*, fig. 2, attached to the beam by an eye screwed near to the coulter-mortise.

715. Like all subsoil-ploughs, the Tweeddale subsoil-trench-plough is only used in co-operation with another plough, which, as its coadjutor, is always the Tweeddale plough, the two being purposely made to act together when the soil is to be trench-subsoiled. An elevation of both these ploughs, as they appear in actual operation, is represented in fig. 272, where the Tweeddale

Fig. 272.



THE TWEEDDALE SUBSOIL-TRENCH-PLOUGH AND THE TWEEDDALE PLOUGH IN CONJOINT OPERATION.

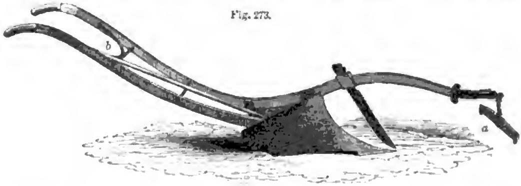
plough *b* is taking its furrow of 13 inches in depth below the surface *d*, followed by the trenching subsoil-plough *a* going 6 inches deeper, below the sole of the Tweeddale plough, making the trench-subsoiling 19 inches deep. The wheels of the subsoil-plough *a* are seen resting upon the sole of the furrow just taken out by the Tweeddale plough *b*, while the tail-board *c* appears doing its office of elevating the slice of subsoil 8 inches, and thus forming a continuous succession of a void space under its extremity, and again filling up the void with a mixture of the surface-soil and subsoil. The compound action of both ploughs is not a mere ripping through the subsoil, as is the case with ordinary subsoil-ploughs, but is a complete mixing of a part of the surface-soil with the stirred-up subsoil—more complete than trenching with the spade.

716. Such is the pulverised state of the soil and subsoil after being thus trench-subsoiled, and such is the easy action of the Tweeddale plough, that we have seen two horses turn over a furrow 12 inches deep, on ploughing a seed-furrow for wheat after potatoes, with as much ease as they would have turned over a furrow of 7 inches deep, in the same circumstances, with the East-Lothian plough.

717. *The Small Plough.*—Fig. 273 is a view in perspective of an iron small

plough, which, as is evident from the figure, is exactly similar in construction to the common East-Lothian plough, Plate I., but in such smaller dimensions and lightness that a single horse can work it with ease. A single swing-bar

Fig. 273.



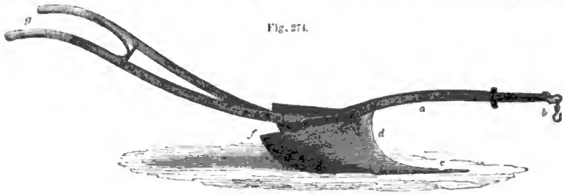
THE SMALL PLOUGH.

a attached to the bridle is all the means of attachment required for the use of the horse. To afford the stilts the means of resisting any cross-strain upon them, an iron rod *b* is fixed at one end to the inside of the land-side of the plough, and on being brought diagonally across the stilts, is fastened at the other end to the right-hand or little stilt, a little below the handle. The other parts of the implement require no particular description.

718. A species of ploughing executed with the small plough, in the same manner as drilling in the single method with the common plough, and in form exactly resembling it on a diminished scale, is named *ribbing*. This plough was once used for paring away the earth along the sides of turnip-drills; but the operation is now performed by means of scufflers and drill-harrows.

719. *The Double Mould-Board Plough*, fig. 274, is a representation of a

Fig. 274.



THE DOUBLE MOULD-BOARD PLOUGH.

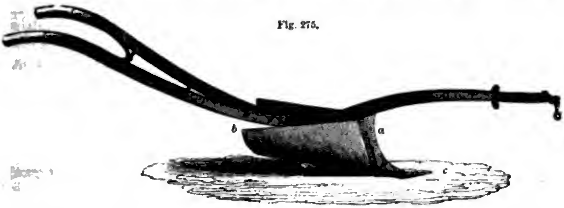
common double-mould-board iron plough equipped for the purpose of earthing-up the turnip crop, for which it is much employed. The framework of it is pretty much in form of the common plough, except that the beam *a* lies right in the central line of the whole plough. The bridle *b* is variously formed, according to the taste of the maker, but always possessing the properties of varying the point of draught upward and downward, as well as right and left. The breast *d* is a shield forming part of the cast-iron body-frame. The share *e* is plain on both sides, spear-pointed, and set upon the head of the cast-iron body-frame. The right and left mould-boards *f f* are hinged to the edge of the shield *d* with drawing hinge-pins, and they are supported behind by a jointed iron-strap affixed to the back of each mould-board, and which slide through a socket in the body-frame, where the tails of both straps are secured by means of a pinching-screw, setting the mould-boards at any required width behind. The handles *g* are bolted on each side of the beam, as seen at *f f*, and are supported near the helves by the usual stretcher and bow. The dimensions of this plough are—from the breast *d* to the point of the beam *b*, 3 feet 6 inches; from *d* to extremity of mould-board *f*, 2 feet 6 inches; and from *d* to end of helve, 6 feet 6 inches, the extreme length of the plough being 10 feet. The height of the mould-board, where it joins the shield, is 12 inches, and at the point *f* 10 inches; length of share, 16 inches. The mould-boards of such ploughs are liable to great variation in their form; some of them have little or no twist, and others variously contorted. Those of the present figure have been selected as possessing all the requisite qualifications for an earthing-up plough. At the fore-edge, where they join the shield, the surface of the mould-boards is nearly in a straight line, and along the upper edge they are slightly convex; from these two lines they twist gradually, rounding away below towards the tail, so as to leave the furrow of a round-bottomed trough shape. This plough being only employed in pulverised soil, no coulter is required.

720. Such a double mould-board plough as has just been described in fig. 274, would make drills as wide as are required; but when its mould-boards are set to make 27-inch drills, it is found that they are too wide below to allow the plough to go as deep as to give the drills their proper elevation of 13½ inches.

721. A *drill* is the triangular ridglet of earth upon which turnips and potatoes are now generally cultivated.

722. *The Double Mould-Board Plough for Drilling Land.*—Where the double mould-board plough is used for forming drills, it is made as large as the common plough, and the mould-board is made to fit the shield *a*, fig. 275; it then

Fig. 275.



THE DOUBLE MOULD-BOARD PLOUGH, FOR MAKING DRILLS.

stretches away to a length of 2 feet 6 inches along the upper edge, the point *b* being at a height varying from 11 to 14 inches above the sole-line. At this point the depth of the mould-board is only 6 inches, so that the lower edge runs off at a considerable elevation; and the surface having not more than 3 inches of twist, it is the lower edge only of the board that effects the purpose of laying up the earth to form the drill. The sock *c* should be double-tenoned, to take a firm hold of the ground. No coulter is required in forming drills with a double mould-board plough.

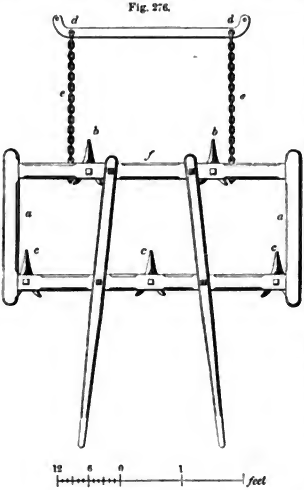
723. In working the double mould-board plough for the purpose of forming drills, there is frequently a marking-bar jointed to the beam immediately before the breast *a*, fig. 275; the bar folds to either side, and having an adjustable double-edged scraper fitted to it, a rut is drawn on the surface of the ground at the proper distance for the centre of the next furrow.

724. This form of double mould-board plough is a most efficient implement in drilling land, for it not only makes drills as fast again as the common plough, but it makes both shoulders of the drill equal, and thereby promotes undisturbed the upright growth of the germ of the potato and bean plants.

725. *The Ribbing Coulters.* — As the small plough, fig. 273, only makes

one rib at a landing, and as only two small ploughs are to be found on most farms, and as it may be desirable in some seasons, and particularly in a late season, and on heavy land, to rib a considerable extent of ground in a short time, instead of ploughing up the waxy cloddy soil from below, an implement that will do more work in the same time, and in the same manner, should be preferred to the small plough. Such an implement may be found in the ribbing coulters, fig. 276, which may be drawn by one or two horses, according to the nature of the soil, and which makes 5 drills at a time, of a sufficient depth to cover the seed. It consists of a frame *a a*, bearing 5 coulters *b b*, *c c c*, which divide the surface-soil exactly as the double mould-board plough for drilling, fig. 275, into two furrows, but on a much smaller scale. Two coulters, *b b*, are placed in the foremost part of the frame, and three, *c c c*, in the hindmost part, at intermediate distances, and forming 5 drills, embracing four spaces of 12 inches each in width. The horse is attached by the hooks of the plough-chains to the eyes in the bar *d d*, which is fastened to the frame *a a* by the chains *e e*, which are 2 feet long, and by their weight, together with that of the bar *d d*, give steadiness to the draught.

Fig. 276.

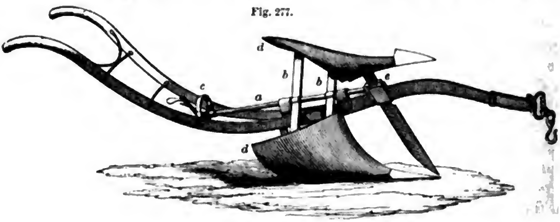


THE RIBBING-COULTERS.

726. This implement might be rendered more important, if requisite, by attaching to it, by a shackle at *f*, the swing-trees of the common plough, with two horses; and the framing might also be mounted on an axle and wheels.

727. *Wilkie's Turn-wrist Plough.*—The only implement which can turn over the furrows in one direction is the turn-wrist plough: the one invented by the late Mr Wilkie, Uddingston, is considered the best, and is represented in perspective in fig. 277. It has two mould-boards *d d*, whose inside faces are attached together by means of two iron bars *b b*, so as when one mould-board is in operation the other is elevated in the air. These bars are attached at right angles to an iron spindle *a*, which at one end *c* is seated in a

Fig. 277.



WILKIE'S TURN-WRIST PLOUGH.

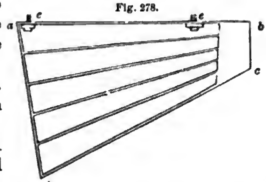
plummer-block, and furnished with a crank-handle, and at the other terminates in the coulter-box *e*. To the crank-handle *c* is attached a spring which falls into a notch on each side of a semicircle, as the spindle *a* is turned round to place either mould-board in its position for ploughing; and while doing this it also acts upon the head of the coulter so as to cause its point to stand over the point of the sock, which in this implement is attached to the mould-board instead of the head. This plough acts in the same manner as the common plough, when the mould-board is set, as seen in the figure, the furrow-slice being turned over to the right hand; and on coming to the land's end, the other mould-board is brought down on the left-hand side of the plough, and by it the furrow-slice is turned over to the left hand—which is still placed in the same direction as when the ploughing was turning over the furrow-slice to the right hand, in moving in the opposite direction. The ploughman requires some practice to become acquainted with the working of this plough, as he does not at first feel at home when the furrow-slice is turning over to the left hand.

728. In this form of turn-wrist plough, the method of effecting the adjustment of the coulter simultaneously with that of the mould-board is simple and ingenious. The slot or coulter-mortise in the beam, instead of being made of uniform width throughout its depth, is considerably wider at the top than at the bottom, the taper or slope being equal on each side: this allows the upper part of the coulter-stem a considerable play in its mortise; so that it can be moved from side to side within a certain range, corresponding to the difference between the widths of the top and bottom of the coulter-mortise. At the end of the coulter-box *e*, fig. 277, nearest the stilts, a small recess or groove is cut. To the end of the spindle *a* a small eccentric is attached, which fits into this groove in the coulter-box. As the crank-handle is turned round, adjusting the mould-board as required, the eccentric acts on the side of the groove in the coulter-box, and moves with it the coulter-stem from one side of the mortise-slot to the other.

729. The turn-wrist plough has long been in use in the south of England, principally in Kent, but it seems to possess no particular advantage over the common plough in flat grounds. On steep sloping ground, however, it is useful in maintaining the furrow-slice up-hill by ploughing such soil diagonally or across the slope, and thereby preventing the baring of the surface at the upper part of the sloping ground by the descent of the soil toward the lower part, which in time the common ploughing of the land on ridges up and down the slope would probably effect.

730. *Ploughs for lifting Potatoes.*—The ordinary plough is sometimes used for taking up potatoes; but to prevent the coulter cutting them, it is recommended to take it out, the sock lifting the potatoes from the bottom of the drill, and the mould-board turning them out upon the surface of the ground.

Fig. 278.



LAWSON'S BRANDER FOR LIFTING POTATOES.

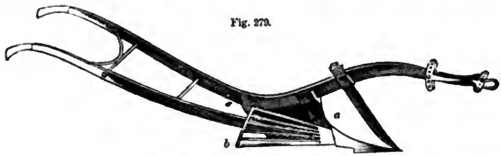
731. The double mould-board plough, fig. 275, acts better for taking up potatoes than the common plough.

732. *Lawson's Brander Potato-Lifter.* — A simple instrument, which may be substituted in the plough for the mould-board, and for turning the potatoes out of the ground, was contrived by Mr Lawson of Elgin. It consists of six malleable-iron bars, fig. 278, the outer ones $\frac{5}{8}$ of an inch square, the inner ones $\frac{1}{2}$ an inch in dia-

meter, joined together in the form of a brander or gridiron, 26 inches long from *a* to *b*, 5 inches broad from *b* to *c*, the bars being attached at this end to a plate of iron; the length from *c* to *d* is 27 inches, the breadth from *a* to *d* 18 inches. This arrangement gives an opening between the rods at the widest end of rather more than 3 inches in width. The brander or gridiron thus constructed is attached to the right side of the head and stilt of a plough, in lieu of the mould-board, by the screws *e e*.

733. As shown in fig. 279, the fore-end, *b c*, fig. 278, of the brander is placed

Fig. 279.



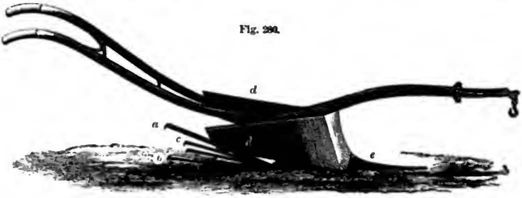
PLOUGH WITH LAWSON'S BRANDER ATTACHED.

close behind the sock *a*, fig. 279, and the plane of its face is so bent down, that while its upper angle *e* is 8 inches, its lower angle *b* is only 4 inches above the sole-line of the plough.

734. The mode of operation of the brander is, that while the earth partly passes through it, and is partly pushed aside by it, the potatoes are left exposed upon the surface of the ground on the right hand of the ploughman.

735. *Plough-Graip for lifting Potatoes.*—In fig. 280 we give a new form of

Fig. 280.



PLOUGH-GRAIP FOR LIFTING POTATOES.

potato-plough. The peculiarity of this implement consists in the adaptation to the double mould-board plough, fig. 275, of a graip *a b*, which is attached to the sole, and the bars of which incline upwards, so that their longest extremities shall be 9 inches above the sole-line of the plough.

736. In fig. 281 is the graip on a larger scale. The two outer ribs *a b*, *a b* are flat, rounded at the edges; their length, from the neck *a*, where they join the flat sole *c*, being 2 feet 4 inches, and their breadth 1½ inches. The two central bars *d e* are round, with the exception of the parts near the point where they join the sole *c*, their length being, from the point to *d* or *e*, 1 foot 7½ inches. Fig. 282 gives a side-view of the bars, showing their attachment to the plough at *a c*, the hooked points of the bars at *b* and *e*, and the angle of inclination *b f* of the bars, 9 inches above the sole of the plough.

737. The mode of operation of the plough-graip is, that while the long sock *e* of the double mould-board plough, fig. 280, is passing under the drill of potatoes, the drill is divided in the middle by the mould-boards *d d*, which, being

cut off in their lower part, permits the plough to penetrate the drill to the bottom. The earth, when thus divided, passes partly up the short inclined inside bars *c*, and in falling through them leaves the potatoes exposed on the surface, and partly is lifted up and cut through by the long outside bars *a b*, *a b*, leaving the potatoes exposed on each side of the tail of the mould-boards. The hooked ends of the bars *b e*, fig. 282, serve to rake to the surface such potatoes as may have remained concealed in the ground. This simple implement brings almost every potato to the surface, and the passing of harrows afterwards over the ground as completely exposes the crop as perhaps can be done by mechanical means.

Fig. 281.

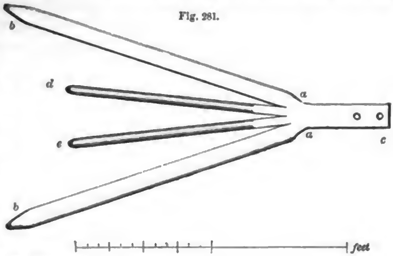
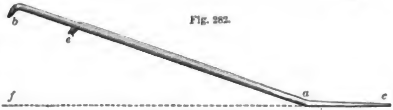


Fig. 282.



DETAILS OF THE PLOUGH-GRAIP.

738. *Hanson's Potato-Digger.*—In fig. 283 we give a perspective view of a

Fig. 283.

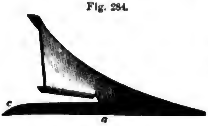
HANSON'S POTATO-DIGGER.

potato-digger invented by Mr Hanson, and manufactured by Mr Coleman of Chelmsford. It is highly spoken of by practical men who have tested its use in the field. The essential parts of the machine consist of a flat broad share and revolving forks. The share *g* is attached by a "stem" *k*, capable of adjustment, to the framing; this share goes under the potatoes, effectually breaking up and pulverising the soil, and freeing the potatoes from the drill. In close contact with the upper surface of the share, a series of two-pronged forks *h h* revolves. These forks, eight in number, project from the periphery of a disc, which receives motion from the driving-wheels *b b* of the machine. The shaft of the digger-disc is placed transversely to the length of the share. As the tendency of the revolving forks *h h* is to throw up or scatter the potatoes to a considerable distance laterally, a strong netting, not shown in the figure, is attached to the side opposite to that at which the stem *k* of the share is fixed. The potatoes, as they are thrown up, are arrested by this netting, and are laid along the drills in regular rows. Not the least important feature of the machine is said to be the ease with which the unexhausted manure is mixed with the soil, and the weeds left on the surface. We should, however, dread injury to the potatoes themselves by this mode of lifting them, by such a violent action of the forks.

739. In fig. 283 *a* is the framing; *b b* the main carrying or driving wheels, which embrace a drill of potatoes; *c c* the fore-wheels, supported by a screwed stem *d*, which is raised or lowered in its seat through the medium of the pinion *e*, the teeth of which engage with the threads of the screw on *d*. Motion is given to the pinion *e* by the handle *f*. The depth to which the share *g* penetrates the soil is thus regulated. The revolving forks are shown at *h h*; the workman guides the implement by the handles *i*. The machinery, consisting of an assortment of wheels giving motion to the disc carrying the forks *h h* by one of the driving-wheels *b*, is contained in the casing suspended between the wheels *b b*.

740. *Paring Ploughs.*—The share of the common plough cuts a furrow-slice at most 10 inches broad, and its depth is 4 or 5 inches in lea. As the turf in paring requires to be no thicker than will remove the herbage, it need never exceed 3 inches in thickness, and the plough will scarcely be held steady at less depth; and as that depth would be easy work for the horses, a greater breadth of slice may be turned over than a share of the ordinary form can do. The only mode of causing the share to do more work is by extending the feather outwards to 12 or 15 inches, as desired for the breadth of the turf. Fig. 284 represents the share of the common plough, where at *a* the breadth of the common feather is 10 inches, but on welding a wing 3 inches in breadth, and having a sharp edge upon the outer point *a* of the feather, the paring-face may be increased to 15 inches in breadth, from *c* to the land-side of the share. When the paring has been accomplished the wing *c* can be cut off, and the share is again fit for ordinary use.

Fig. 284.

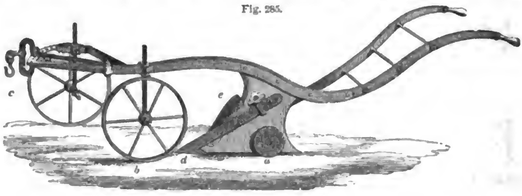


THE PARING-SOCK.

741. The paring-plough used in parts of England in the fens, pares the turf by means of two angular shares with the wings facing each other, and just crossing the centre line, one being a little before the other; and they are attached to shanks, placed in front of the mould-board, upon which the turf is raised in a manner similar to the furrow-slice in ordinary ploughing, and is set on its edge upon the pared ground, ready to be dried, as neatly as if done by the hand.

742. *Leicester Paring-Plough.*—A better paring-plough, fig. 285, is manufactured by Mr Thomas Johnson, engineer, Leicester. Its peculiar parts consist

Fig. 285.

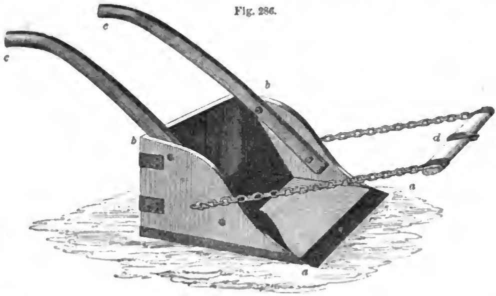


THE LEICESTER PARING-PLOUGH.

of a small wheel *a*, attached to near the heel, to support the sole along the pared ground. The near wheel *b* moves in front of the coulter *d* upon the unpared surface, while the off wheel *c* moves upon the pared surface. By the adjustment of these two large wheels, the thickness of the turf to be pared is determined. The coulter *d*, sloped at a low angle, 28°, cuts the turf, and the mould-board *e* sets it upon its edge, curled up to be dried. The plough cuts the turf 14 inches in breadth, and from 1 to 2 inches in thickness. The cost of the implement is £5, 10s.

743. *Levelling-Box or Scoop.*—In fig. 286 we give a sketch of the levelling-

Fig. 286.



THE LEVELLING-BOX OR SCOOP.

box used to reduce the inequalities of ploughed land. The inequalities alluded to are slight hollows, low heights running across several ridges, making one side or part of a ridge higher than the other, or part of the head-ridge higher than the ridges, and suchlike blemishes. The figure represents one to be worked by two horses, furnished with fixed handles and draught-chains. The two sides *b a*, *b a*, having the same depth where they join the back, are curved off to nothing at the front. It is requisite for strength that it be made of hard-wood; but the common willow, from its toughness and lightness, is perhaps better adapted than any other wood for this purpose. The sole of the scoop is armed with a strong shoeing of iron, terminating in a sharp cutting edge. Two skeds or bolsters are fixed on the lower side of the sole, thinned off forward to give facility of entrance in the soil to the cutting edge of the scoop, and upon which it runs like a sledge when filled. All the corners are strongly bound with iron plates, and the skeds upon which it runs are covered with strong sheet or hoop iron. The handles *b c*, *b c* are bolted to the sides, and so fitted as to bring the extremities *c c* to a convenient distance for being held in the hands of the conductor. The draught-chains, with their stretcher *d*, are attached to an eye-bolt or a staple on either side of the scoop.

744. The levelling-scoop is frequently fitted up in a manner somewhat different in the mode of attaching the handles. A strong gudgeon is fixed in each side at the place of attachment of the chains; and the terminations of the chains being an eye-bolt or link, it is passed upon the gudgeon. The handles, in place of being fixed to the sides, have an eye formed in their end and strengthened with iron, which passes also upon the gudgeon, and are held there by a washer and cotrel. A second pair of gudgeons are strongly fixed, one upon each corner of the box at the back, in a position that will pass through the handles when they are at a proper height. The handles are here

also pierced and defended with iron, so as to slide freely off and on upon these second gudgeons, and their extremities brought, as before, to a convenient width.

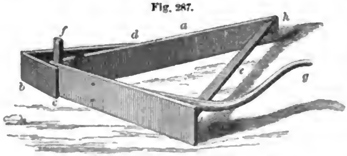
745. The mode of using the levelling-box is this: After the part of the ground intended to be made lower has been ploughed by the common plough, the driver of the levelling-box brings his horses over the ploughed land, and raises the handles *c* so as the sharp front *a a* of the box enters the ground and scoops as much earth into the box as to fill it, when the driver presses upon the handles and causes the loaded box to slide upon its hind part until he comes to the spot which has to be raised up. He then lets go the handles, and the sharp front edge catching the ground upsets the box with its contents, the horses walking on while the handles strike against and remain upon the stretcher *d*. A short stout piece of rope being attached to one of the handles, the driver, while the horses are returning to the ploughed ground, again suddenly, by a jerk of the rope, replaces the box on its bottom, when it is again ready for use.

746. The levelling-box produces its effect relatively very quickly, for while it is lowering a height by taking away the superfluous earth, it is filling up a hollow with the same material.

747. In the form of handles described in par. 744, the box recovers its working position by turning over of itself after the earth is emptied out of it; this it effects by means of the gudgeons on the corners catching hold of the ground.

748. *Hepburn's Mountain Turn-wrist Snow-Plough.*—" To enable the plough to clear tracks for the sheep along the hill-sides, it is necessary it should be made to throw the snow wholly to the lower side. To effect this," says Mr Hepburn of Colquhalzie, the inventor, " I caused to be fitted to the plough *a*,

Fig. 287.



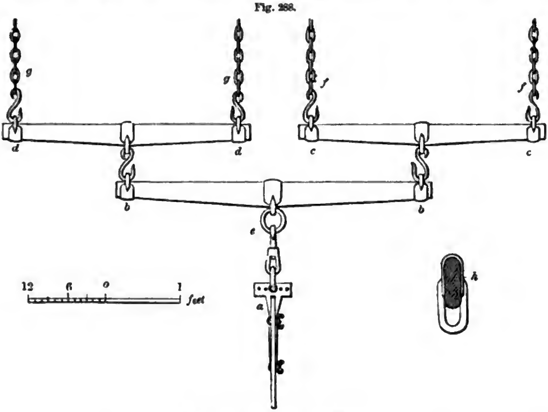
HEPBURN'S MOUNTAIN TURN-WRIST SNOW-PLOUGH.

fig. 287 (the body of which forms an isosceles triangle whose sides are 7½ feet, and its base 6 feet in length, the depth of the sides being 15 inches), a shifting head *b c d* with unequal sides, one, *b c*, being 18 inches, the other, *b d*, 30 inches long, fixed by iron pins passing through two pairs of eyes, as at *c*, attached to the head and to the sides of the plough respectively, so as to bring the point of the attached head of the plough nearly into the line of its upper side, or next the hill. The stilt *g* at the same time was made movable by a hinge-joint at its anterior extremity, fixed to the bottom of the head from the post *f*, so as to be capable of being fixed to the cross-bar or stretcher *e*, either in the line bisecting the angle, as at *e*, which is the position for level ground, or in the line, alternately, of either of the sides *b a* or *b c*, when to be used on a declivity. The draught-chain is fixed, not to the shifting head, but to the upright frame-post *f*, in the nose of the plough, which rises 10 or 12 inches above the mould-boards. When the plough so constructed is to be worked along a declivity, with the left hand towards the hill, the shorter limb of the shifting head is fixed on the left side of the plough, near the point, and the longer limb on the right side, towards the middle; and the stilt *g* being fixed in the left extremity of the cross-bar *e*, nearly in a line with the temporary point, the plough is necessarily drawn in the direction of its left side, so as to throw the snow wholly to the right down the hill. When the plough is to return across the declivity, with its right side to the hill, the movable head is detached by drawing out the pins at *c*, is turned upside down, and fixed in the reverse position; the shorter limb being attached to the right side, and the longer to the left side of the plough, while the stilt g is brought to the right extremity h of the cross-bar. The plough is then drawn in the direction of the right side, and the snow is thrown wholly to the left, near the lower side. Should the lower side of the plough show a tendency to rise, it may either be held down by a second movable stilt, fixed to the middle e of the cross-bar, or a block of wood or other ballast-weight may be placed on that side of the plough. The plough will be found to remove considerably more than its own depth of snow. When a plough of 1 foot high passes through snow 18 inches or 2 feet deep, very little of the snow falls back into the track, and what does so fall is easily cleared out by the plough in returning."*

749. Such a snow-plough is eminently useful in breaking up deep-crusted snow upon hill-pasture late in spring, to the dissolving influences of the sun and wind.

750. *Swing-trees.*—The *swingle* or *swing-trees*, *whipple-trees*, *draught-bars*, or simply *bars*, for by all these names are they known, are those bars by which horses are yoked to the plough, harrows, and other implements. In the plough-yoke a set of swing-trees consists of three, as represented in fig. 288, where a

Fig. 288.



THE SWING-TREES FOR TWO HORSES.

points out the bridle of the plough, b b the main swing-tree attached immediately to the bridle, c c the furrow or off-side little swing-tree, and d d the land or nigh-side little swing-tree, arranged in the position in which they are employed in working. The length of the main-tree, between the points of attachment for the small trees, is generally $3\frac{1}{2}$ feet, but this may be varied more or less; the length of the little trees is usually 3 feet between the points of attachment of the trace-chain, but this also is subject to variation.

751. Swing-trees are, for the most part, made of wood, oak or ash being most generally used; but the former, if sound English oak, is by much the most

* *Prize Essays of the Highland and Agricultural Society*, vol. xiii. p. 191.

durable, though good Scotch ash is the strongest so long as it remains sound, but it is liable, by long exposure, to a species of decay resembling dry-rot.

752. *Rules for ascertaining the Strength of Swing-trees.*—As it is always of importance to know the why and wherefore of everything, we shall here point out how it may be known when a swing-tree is of a proper degree of strength. A swing-tree, when in the yoke, undergoes a strain similar in practice to that of a beam supported at both ends and loaded at the middle, and the strength of beams or of swing-trees in this state is proportional to their breadths multiplied into the square of their depths and divided by their lengths.

753. It is to be understood that the *depth* here expressed is that dimension of the swing-tree that lies in the direction of the strain, or what, in the language of agricultural mechanics, is called the *breadth* of the swing-tree.

754. To apply the above expression to practice, suppose a swing-tree of 3 feet in length between the points of attachment for the draught, that its breadth is $1\frac{1}{2}$ inches and depth 3 inches, and another of the same breadth and depth, but whose length is 6 feet, then in the case of the first we have $\frac{1.5 \times 3 \times 3}{3 \text{ feet}} = 4.5$; and in the second we have $\frac{1.5 \times 3 \times 3}{6} = 2.25$, the strength of these two being as 2 to 1; and to make the 6-feet swing-tree of equal strength to the 3-feet ones, the *breadth* must be increased directly as the length, that is to say, doubled, or the depth increased, so that its *square* shall be doubled also. Hence, a swing-tree of 6 feet long, and having a breadth of $1\frac{1}{2}$ inches and depth $4\frac{1}{4}$ inches, will be equal in strength to the 3-feet swing-tree with a breadth of $1\frac{1}{2}$ inches and depth of 3 inches; but the depth remaining equal, the breadth is required to be *doubled*, or made 3 inches for the 6-feet swing-tree.

755. To find the absolute strength of a bar or beam, situate as above described, we have this rule: Multiply the breadth in inches by the square of the depth in inches, divide the product by the length in feet, and multiply the quotient by the constant 660 if for oak, or by 740 if for ash, the product will be the force in pounds that would break the swing-tree or the beam.* Here, then, taking the former dimensions as of a small swing-tree, $\frac{1.5 + 3^2 \times 740}{3} = 3330$ lb. the absolute force that would break the tree; but taking into account the defect that all woods are liable to break from crossing the fibres, and other contingent defects, we may allow $\frac{1}{2}$ to go for security against such contingencies, leaving a disposable strength equal to 1665 lb. The usual force exerted by a horse in the plough does not exceed 168 lb.; but it occasionally rises to 300 lb., and on accidental occasions even to 600 lb.; but this is not much beyond $\frac{1}{3}$ of the disposable strength of the 3-feet swing-tree when its breadth and depth are $1\frac{1}{2}$ inches and 3 inches. The depth of such trees may therefore be safely reduced to $2\frac{1}{2}$ inches, and still retain a sufficient degree of strength to resist any possible force that can come upon it.

756. In the large swing-tree the same rule applies: Suppose its length between the points of attachment to be 3 feet 9 inches, its breadth $1\frac{3}{4}$ inches, and depth $3\frac{1}{2}$ inches, the material being ash as before, then $\frac{1.75 \times 3.5^2 \times 740}{3.75} = 4233$ lb.; reducing this $\frac{1}{2}$ for security, there remain $2116\frac{1}{2}$ lb., but the greatest force that

* TREDGOLD'S *Carpentry*, art. 110.

may be calculated upon from 2 horses is 1200 lb.: we have, therefore, nearly double security in this size of large swing-tree.

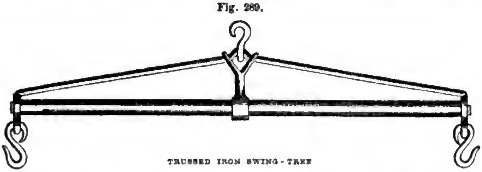
757. In proportioning the strength of swing-trees to any particular draught, let the greatest possible amount of force be calculated that can be applied to each end of the tree; the sum of these will be the opposing force as applied at the middle, and this may be taken, as in par. 755, at 600 lb. for each horse; but for security let it be 3 times, or 1800 lb. each horse h, any number of horses being $m\,h$; and having fixed upon a breadth b for the tree, and l the length, c being the constant as before, then the depth d will be found thus, $\frac{l \times m\,h}{b \times c} = d^2$; or, in words, multiply the length into as many times 1800 lb. as there are to be horses applied to the tree, divide the product by the *constant* —740 for ash, or 660 for oak—multiplied into the breadth, the quotient will be the square of the depth, and the square root of this will be the depth of the swing-tree, with ample allowance for assurance of strength. In all cases the depth at the ends may be reduced to $\frac{3}{4}$ of that of the middle.

758. *Swing-Trees for Two Horses.*—Wooden swing-trees ought always to be fitted up with clasp-and-eye mounting of the best wrought-iron from 2 to $2\frac{1}{2}$ inches broad, about $\frac{3}{16}$ inch thick in the middle parts, and worked off to a thin edge at the sides; the part forming the eye may range from $\frac{1}{2}$ inch diameter in the centre eye of the large tree to $\frac{3}{8}$ of an inch in the end clasps of the small trees; and they are applied to the wood in a hot state, which, by cooling, makes them take a firm seat. In the main tree, the middle clasp has usually a ring or a link e, fig. 288, welded into it, by which the set is attached to the hook of the plough's bridle; the two end-clasps have their eyes on the opposite edge of the swing-trees, with sufficient opening in the eyes to receive the S hooks of the small tree. The small trees are furnished with the S hooks, by which they are appended to the ends of the main-trees; and end-clasps are adapted to receive the hooks of the trace-chains $f\,f$, $g\,g$, a small part only of which is shown in the figure. The detached figure h is a transverse section of a tree showing the form of the clasps, the scale of which is double the size of the principal figure in the cut.

759. Though wood has hitherto been the material chiefly used for swing-trees, there have been some successful trials of malleable-iron for the purpose. These have been variously constructed, in some cases entirely of sheet-iron turned round into a form somewhat resembling the wooden trees; but in this form, either the iron must be thin, or the bar must be inconveniently heavy; if thin, durability becomes limited, by reason of the oxidation of the iron acting over a large surface, and soon destroying the fabric.

760. Another method has been tried, consisting of a straight welded tube of

Fig. 289.



TRUSSED IRON SWING-TREE

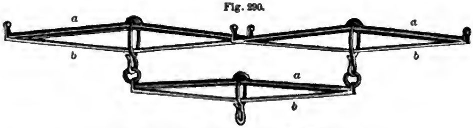
malleable-iron, about 3 feet long and $\frac{3}{4}$ inch diameter. In this tube, acting as a strut, a tension-rod, also of malleable iron, is applied with a deflection of 4 inches, the extremities of the tension-rod being brought into contact by welding or riveting with the ends of the tubular strut, and eyes formed at the ends and middle, for the attachment of the hooks and chains. A tree thus formed, fig. 289, is sufficiently strong for every purpose to which it is applied, while its weight does not exceed 7 lb.; and the weight of a wooden tree, with its mounting, is frequently 8 lb. The structure, however, seems rather clumsy to the eye.

761. A third method has been to form a diamond-shaped truss of solid-iron rods, the diamond being very much elongated, its length being 3 feet, and its breadth about 4 inches, with a stretcher between the obtuse angles.

762. The price of a set of common wooden trees, with the iron mounting, is 12s., and of the iron trees, 18s.

763. Another form of trussed whipple-trees is given in fig. 290, which represents that introduced by Messrs Ransome and Sims, Ipswich. This form has a high character for strength and lightness. It is made entirely of malleable-

Fig. 290.



RANSOME AND SIMS' TRUSSED IRON WHIPPLE-TREES.

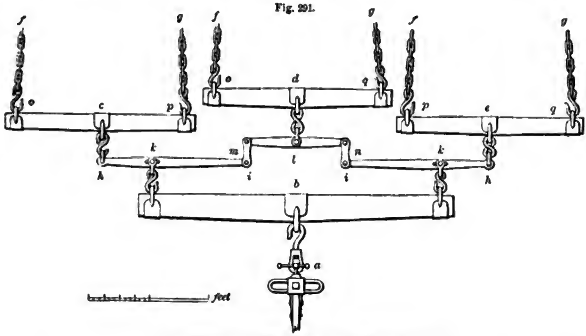
iron; the larger bars or struts *a a a* are usually of tubular iron from 1 inch to $1\frac{1}{2}$ inch in diameter; the tension-rods *b b b* of rod-iron from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in diameter.

764. *Swing-trees for Three Horses.*—The foregoing remarks apply, so far as arrangement goes, to the common two-horse swing-trees; but the various modes of applying horse-power, both as regards number and position of the horses, require further illustration. The next we shall notice, therefore, is the *three-horse yoke*, of which there are various modes, the simplest of which is, first, a pair, working in the common trees, fig. 288; and for the third horse, a light chain is attached by a shackle to the middle of the main bar *b b*. To this chain the third horse is yoked, taking his place in front of the other two, in unicorn fashion. This yoke is defective, inasmuch as there are no means of equalising the draught of the third horse.

765. Perhaps the most perfect method of yoking a three-horse team, whether abreast or unicorn fashion, is that by the compensation-levers, fig. 291—a statical combination, which is at once correct in its equalisation, scientific in its principles, and elegant in its arrangement; and we have to regret our inability to single out the person who first applied it. The apparatus in the figure is represented as applied to the subsoil-plough, *a* being the bridle of that plough; *b* is a main swing-tree, 5 feet in length, and of strength proportioned to the draught of three horses; and *c*, *d*, *e* are three small common trees, one for each horse. The trace-chains are here broken off at *f*, *g* respectively, but are to be conceived as extending forward to the shoulders of the horses. Between the main swing-tree and the three small ones the compensating apparatus is placed, as in the figure, consisting of three levers, usually constructed of iron. Two of these, *h i* and *h i*, are levers of the first order, but with unequal arms, the fulcrum *k* being fixed at $\frac{1}{3}$ of the entire length from the outward end of each; the arms of these levers are therefore in the proportion of 2 to 1, and the entire length of each between the points of attachment is 27 inches. A connecting lever *l*, of equal arms, and 20 inches in length, is jointed to the longer arms *i*, *i* of the for-

mer, by means of the double short links *m*, *n*. The two levers *h i*, *h i* are

Fig. 291.



THE COMPENSATION-LEVER SWING-TREES FOR THREE HORSES

hooked by means of their shackles at *k* to the main swing-tree *b*; and the three small swing-trees *c*, *d*, *e* are hooked to the compensation-levers at *h*, *h* and *l*.

766. From the mechanical arrangement of these levers, if the whole resistance at *a* be taken at 600 lb., *k* and *k* will each require an exertion of 300 lb. to overcome the resistance. But these two forces fall to be subdivided in the proportion of the arms of the levers *h i*, $\frac{2}{3}$ of each, or 200 lb., being allotted to the arms *h*, *h*, and the remaining $\frac{1}{3}$, 100 lb., to the arms *i*, *i*, which brings the system to an equilibrium. The two forces *i*, *i* being conjoined by means of the connecting-lever *m n*, their union produces a force of 200 lb., thus equalising the three ultimate forces *h*, *l*, *h* to 200 lb. each, and these three combined are equal to the whole resistance *a*; and the three horses that are yoked to the swing-tree *c*, *d*, *e* are subjected to equal exertion, whatever may be the amount of resistance at *a* which has to be overcome.

767. The judicious farmer will frequently see the propriety of lightening the labour of some individual horse; and this is easily accomplished by the compensation apparatus. For this purpose, one or more holes are perforated in the levers *h i*, on each side of the true fulcrum *k*, to receive the bolt of the small shackles *k*. By shifting the shackle and bolt, the relation of the forces *h* and *i* are changed, and that in any proportion that may be desired; but it is necessary to observe that the *distance* of the additional holes, on either side of the central hole or fulcrum of equilibrium in the system, should be in the same proportion as the length of the arms in which the holes are perforated. Thus, if the distance between those in the short arm is half an inch, those in the longer arm should be an inch. By such arrangement, every increase to the exertion of the power, whether on the long or the short arm, would be equal.

768. The same principle of compensation has been applied to various ways of yoking, one of which is a complicated form of that just described. The main swing-tree and the compensation levers are the same, except that they may be a few inches shorter in all the arms, and the middle one of the three small swing-trees also shorter. The yoking is performed in this manner: the nigh trace-chain of the nigh horse is hooked to the end *o* of the swing-tree *c*, fig. 291, and his

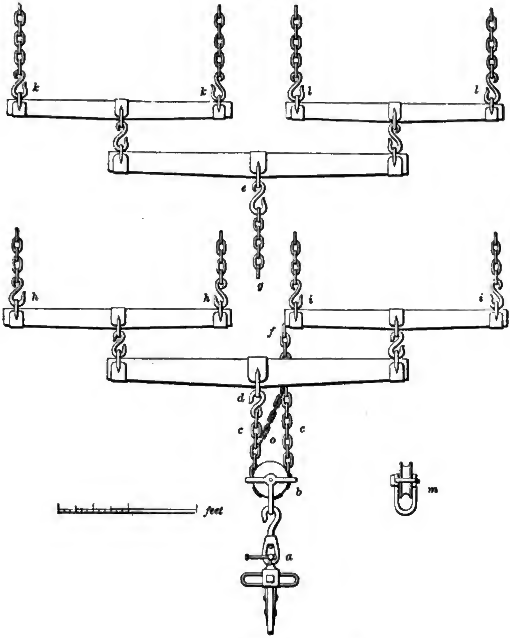
off-side trace-chain to the end *o* of the swing-tree *d*. The middle horse has his nigh-side chain hooked to the end *p* of the swing-tree *c*; while his off-side chain goes to the end *p* of the swing-tree *e*. The off-side horse has his nigh-side chain attached to the end *q* of the middle swing-tree *d*, and his off-side chain to *q* of the swing-tree *e*. This system of yoking is complicated, and though in principle it equalises the forces so long as all the horses keep equally ahead, yet it is in some degree faulty. Whenever the middle horse gets either behind or before his proper station—or out of that position which keeps all the swing-trees parallel to each other—the outside horses have a larger share of the draught upon one shoulder than upon the other; and as this produces an unnecessary fatigue to the animal, it should be avoided. Such irregularity cannot occur with the simple mode of giving each horse his own swing-tree.

769. A modification of this compensation-yoke has been contrived, as we are informed, by Mr Bauchop, Bogend, Stirlingshire. The compensation-levers are formed of wood, and in place of the connecting-lever *l*, fig. 291, a chain, 2 feet in length, connects the ends *i i* of the levers *h i*, *h i*; and in the bight of the chain, as at *l*, a pulley and strap are placed, to which a *soam*-chain is hooked; the pulley from it, oscillating in the bight of the chain, serves the same purpose as the connecting-lever *l*. In this mode of yoking, the horses work in unicorn-team, the middle horse pulling by the soam-chain, instead of the swing-tree *d*.

770. *Swing-trees for Four Horses.—In the yoking of four horses*, various modes are also adopted. The old and simple method is for the plough-horses to draw by a set of common swing-trees, fig. 288; and to the centre of the main swing-tree at *e* a soam-chain is hooked by means of a shackle or otherwise. The leading horses are thus yoked by a second set of common swing-trees to the end of the soam. This is now seldom employed, but an improved method of applying the soam has been adopted in its place, which is represented by fig. 292, where *a* is the bridle of the plough, with its swivel hook. A pulley *b* of cast-iron, 6 inches diameter, mounted in an iron frame, of which an edge-view is given at *m*, is attached to the hook of the bridle. A link-chain *c* is rove through the frame of the pulley, and to the short end of it is hooked the main swing-tree *d* of a set of common swing-trees *h h*, *i i* for the plough-horses. The other end of the chain passes forward to a sufficient distance to allow the leading horses room to work; and to it is hooked the second set of common swing-trees *k k*, *l l* at *e* for the leaders. In the figure, a part of the chain, from *f* to *g*, is broken off; but the full length is about 11 feet. In this yoke, the trace-chains of the nigh-side hind horse are hooked to the swing-trees at *h h*, and those of the off-side horse at *i i*, the leaders being yoked at *k k* and *l l* respectively. In this arrangement, the balance of forces is perfectly preserved; for the hind horses and the leaders, as they pull at opposing ends of the chain passing round a pulley, which must inevitably be always in equilibrium, each pair of horses has an equal share of the draught; and from the principles of the common swing-trees through which each pair acts, the individual horses must have an equally perfect division of the labour, unless this equilibrium has been removed for the purpose of easing a weaker horse. In order to prevent either the hind horses or the leaders from slipping too much ahead, it is common to apply a light check-chain *o*, of about 15 inches long, connecting the two parts of the main-chain, so as to allow only a short oscillation round the pulley, which is limited by the check-chain. When this is adopted, care should be taken never to allow the check-chain to remain upon the stretch; for if it do so, the advantage of equalisation in the yoke is lost, and it becomes no better than the simple soam. In all cases of using a

long chain, that part of it which passes forward between the hind horses must be borne up by means of attachment to their back-bands, or suspended from their collars.

Fig. 292.

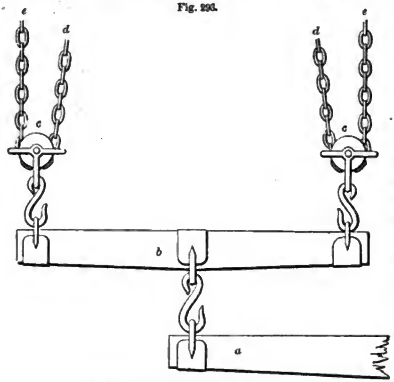


THE CROSS-BALANCE YOKE FOR FOUR HORSES.

771. Mr Stirling of Glenbervie, Stirlingshire, recommends a method of yoking a team of four horses in pairs, the arrangements of which are represented in fig. 293 : *a* is part of a main swing-tree of the common length, *b* a small swing-tree about 4 inches longer than the usual length, but both mounted in the usual form, except that, at each end of the small swing-trees, cast-iron pulleys *c c*, of 3 or 4 inches diameter, and set in an iron frame, are hooked on to the eyes of the swing-tree. The common trace-chains are rove through the frames of these pulleys, as in the figure; the ends *d d* of the chains are prolonged forward to the proper length for the nigh hind-horse, and the ends *e e* are extended to the nigh leader. At the opposite end of the main swing-tree, which in this figure is cut off, the same arrangement is repeated for the off-side horses. The principle of action in this yoke is simple and effective, though different in effect from fig. 292. In fig. 292 the two hind-horses are equalised through the medium of one set of common swing-trees *d*, *h h*, *i i*. The leading horses are alike equalised by their set *e*, *k k*, *l l*, and thus the two pairs balance each other through the

medium of the soam-chain *f g*. In fig. 293, on the other hand, the two nigh-side horses have their forces equalised through the trace-chains *d e*, *d e*, which are common to both, by passing over the pulleys *c c*; and the same holds in respect of the two off-side horses. The couple of nigh-side and of off-side horses, again, are equalised through the medium of one set of swing-trees. In both, therefore, the principle of equalisation is complete, but there is a trifling difference in their economy.

Fig. 293.



THE RUNNING-BALANCE YOKE FOR FOUR HORSES.

772. In the yoke, fig. 292, which we call the *Cross-balance yoke*, the soam-chain and pulley are the only articles required in addition to the everyday gear. In that of fig. 293, which we call the *Running-balance yoke*, there is first the set of swing-trees, which, as they have to resist the force of four horses, must in all their parts be made stronger than the common set, agreeably to the rules we have already given, and to which is added the four pulleys—all of which are only applicable to this yoke. The trace-chain, though not necessarily stronger than those for common use, is required about three times longer than single-horse chains—that is to say, four horses will require the chains of six; but, on the other hand, the chains of the leaders are more conveniently supported when they pass along the sides of the hind-horses, and it is free of the set of swing-trees which dangle behind the leaders of the method, fig. 292.

773. *Swing-trees for Six or more Horses.*—In cases where six or more horses are required, as for subsoiling or draining by the plough, the yoking is accomplished by modifications and extension of the principles here laid down: for example, a team of six can be very conveniently applied with equalised effect by employing the compensation-levers of fig. 292, along with three single swing-trees, with pulleys at each end, and running trace-chains, as in fig. 293.

774. *Of the Draught of Ploughs.*—From the complicated structure of the plough, and the oblique direction in which circumstances oblige us to apply the draught to the implement, some misconceptions have arisen as to the true nature and direction in which the draught may be applied. The great improver of the plough has fallen into this error, and has in some measure been followed by others.* He asserts, "that were a rope attached to the point of the share, and the plough drawn forward on a level with the bottom of the furrow, it would infallibly sink at the point." Were this really the case, it would prove that the centre of resistance of the plough in the furrow must be somewhere below the level of the sole, which is impossible. As the centre of gravity of any body suspended from a point at, or anywhere near, the surface of that body, will always be found in a continuation of the suspending line, supposing it to

* SMALL's *Treatise on Ploughs.*

be a flexible cord; so, in like manner, the centre of resistance of the plough will be always found in the direction of the line of draught. Now, if with a horizontal line of draught from the point of the share, it were found that the point of the share had a tendency to sink deeper into the soil, it would be a clear proof that the plough was accommodating itself to the general law, and that the centre of resistance is below the line of the sole. The fallacy of this conclusion is so palpable, that it would be an act of supererogation to refute it by demonstration, more especially as it never can be of any utility in a practical point of view. We have thought it necessary, however, to advert to it, as it appears to have aided in throwing a mystery over the mode of applying the *line or angle of draught*, which in itself is a sufficiently simple problem.

775. The reasoning hitherto adopted on this branch of the theory of the plough seems to be grounded on the two following data—the *height*, on an average, of a horse's shoulder, or that point in his collar where the yoke is applied; and the *length* of the draught-chains that will give him ample freedom to walk. It falls out fortunately, too, that the angle of elevation thus produced crosses the plane of the collar as it lies on the shoulders of the horse when in draught, nearly at right angles. It is our purpose, however, to show that (keeping out of view some practical difficulties) the plough may be drawn at any angle, from the horizontal up to a little short of 90°, and that it would require less and less force to draw it as the direction of the line of draught approached the horizontal line. It would in all cases be required that the point of the beam, or rather the draught-bolt, should be exactly in the straight line from the centre of resistance to the point where the motive force would be applied. If this force could be applied in the horizontal direction, we should have the plough drawn by the minimum of force. This position, however, is impracticable, as the line of draught would, in such a case, pass through the solid land of the furrow about to be raised; but it is within the limits of practicability to draw the plough at an angle of 12°, and, as will be demonstrated, the motive force required at this angle would be 14 lb. less than is required by drawing at the angle of 20°, which may be held as the average in the ordinary practice of ploughing. A plough drawn at this low angle, namely, 12°, would have its beam (if of the ordinary length) so low, that the draught-bolt would be only 10 inches above the base-line; and this is not an impracticable height, though the traces might be required inconveniently long. On the same principle, the angle of draught might be elevated to 60° or 70°, provided a motive power could be applied at such high angles. In this, as before, the beam and draught-bolt would have to fall into the line of draught as emanating from the centre of resistance. The whole plough, also, under this supposition, would require an almost indefinite increase of weight; and the motive force required to draw the plough at an angle of 60° would be nearly twice that required in the horizontal direction, or $1\frac{1}{8}$ times that of the present practice, exclusive of what might arise from increased weight. We may therefore conclude, that to draw the plough at any angle higher than the present practice is impracticable, and, though rendered practicable, would still be highly inexpedient, by reason of the disadvantage of increased force being thus rendered necessary; unless we can suppose that the application of steam or other inanimate power might require it. Neither would it be very expedient to adopt a lower angle, since it involves a greater length of trace-chains, which at best would be rather cumbrous; and it would produce a saving of force of only 14 lb. on the draught of a pair of horses. Yet it is worthy of being borne in mind, that in all cases there is some saving of labour to the horses, when-

ever they are, by any means, allowed to draw by a chain of increased length, provided the draught-bolt of the plough is brought into the line of draught, and the draught-chains are not of such undue weight as to produce a sensible curvature; in other words, to insure the change of angle at the horse's shoulder, due to the increased length of the draught-chain.

776. In illustration of these changes in the direction of the draught, fig. 1, Plate VI., will render the subject more intelligible. Let *a* represent the body of a plough, *b* the point of the beam, and *c* the centre of resistance of the plough, which may be assumed at a height of 2 inches above the plane of the sole *d e*, though it is liable to change within short limits. The average length of the draught-chains being 10 feet, including draught-bars, hooks, and all that intervenes between the draught-bolt of the plough and the horse's shoulders; let that distance be set off in the direction *b f*, and the average height of the horse's shoulders where the chains are attached being 4 feet 2 inches, let the point *f* be fixed at that height above the base-line *d e*. Draw the line *f c*, which is the direction of the line of draught acting upon the centre of resistance *c*; and if the plough is in proper temper, it will coincide also with the draught-bolt of the beam; *e c f* being the angle of draught, and equal to 20°. It will be easily perceived that, with the same horses and the same length of yoke, the angle *e c f* is invariable; and if the plough has a tendency to dip at the point of the share under this arrangement, it indicates that the draught-bolt *b* is *too high* in the bridle. Shifting the bolt one or more holes downward will bring the plough to *swim* evenly upon its sole. On the other hand, if the plough has a tendency to rise at the point of the share, the indication from this is, that the draught-bolt *b* is *too low*, and the rectification must be made by raising it one or more holes in the bridle. Suppose, again, that a pair of taller horses were yoked in the plough, the draught-chains, depth of furrow, and soil—and, by consequence, the point of resistance *c*—remaining the same, we should then have the point *f* raised suppose to *f′*; by drawing the line *f′ c*, we have *e c f′* as the angle of draught, which will now be 22°; and in this new arrangement the *draught-bolt* is found to be *below* the line of draught *f′ c*; and if the draught-chains were applied at *b*, in the direction of *f′ b*, the plough would have a tendency to rise at the point of the share, by the action of that law of forces which obliges the line of draught to coincide with the line which passes through the centre of resistance; hence the draught-bolt *b* would be found to rise to *b′* which would raise the point of the share out of its proper direction. To rectify this, then, the draught-bolt must be raised in the bridle by a space equal to *b b′*, causing it to coincide with the true line of draught, which would again bring the plough to swim evenly on its sole.

777. Regarding the relative forces required to overcome the resistance of the plough, when drawn at different angles of draught, we have first to consider the nature of the form of those parts through which the motive force is brought to bear upon the plough. It has been shown that the tendency of the motive force acts in a direct line from the shoulder of the animal of draught to the centre of resistance; and referring again to fig. 1, Plate VI., were it not for considerations of convenience, a straight bar or beam lying in the direction *c b*, and attached firmly to the plough's body anywhere between *c* and *g*, would answer all the purposes of draught perhaps better than the present beam. But the draught not being the end in view, but merely the means by which that end is accomplished, the former is made to subserve the latter; and as the beam, if placed in the direction *c b*, would obstruct the proper working of the plough, we are constrained to resort to another indirect action to arrive at the desired effect.

This indirect action is accomplished through the medium of a system of rigid angular framework, consisting of the beam and the body of the plough, or those parts of them comprehended between the points *b*, *h*, *c*, the beam being so connected to the body *a h* as to form a rigid mass. The effect of the motive force applied to this rigid system of parts at the point *b*, and in the direction *b f*, produces the same results as if *c b* were firmly connected by a bar in the position of the line *c b*, or as if that bar alone were employed, as in the case before supposed, and to the exclusion of the beam *b h*.

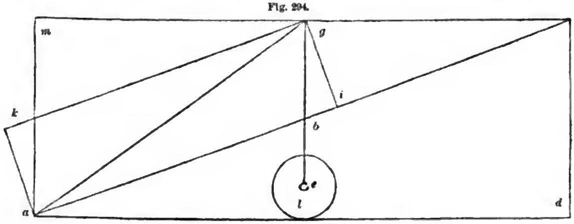
778. *Effect of the Wheel on the Draught.*—Having thus endeavoured to illustrate the causes of the oblique action of the plough, showing that the obliquity is a concomitant following the considerations of convenience and fitness in working the implement, we proceed to show the relative measure of the effects of the oblique action. It is well known that the force of draught required to impel the plough, when exerted in the direction *b f*, may be taken at an average of 24 stones, or 3 cwt., or 336 lb. Analysing this force by means of the parallelogram of forces, if we make the line *b f* to represent 336 lb., the motive force; and complete the parallelogram *b i f k*, we have the force *b f* held in equilibrium by the two forces *i b* and *k b*, the first acting in the ***horizontal*** direction to draw the plough forward, the second acting ***vertically***, to prevent the point of the beam from sinking, which it would do were a horizontal force only applied to the point of the beam. The relation of these forces *i b* and *k b* to the oblique force will be as the length of the lines *i b* and *k b* to the line *b f*, or the line *i b* will represent 322 lb., while the oblique force is 336 lb., and the force *k b* 95 lb. This last force is represented as *lifting* the beam vertically by suspension, but the same result would follow if the beam were supported by a *wheel* under the point *b*; the wheel would then bear up the beam with the same force as that by which it was supposed to be suspended, 95 lb. But to carry out the supposition, let the draught now found be applied horizontally from the point *c*. As the plough would then have no tendency either to dip or rise, the force *k b* vanishes, leaving only the direct horizontal force *c e*; hence, were it possible to apply the draught in a horizontal direction from the point of resistance *c*, the resistance of the plough would be 322 lb., instead of 336 lb.

779. But to return to the previous position of the draught, and still supposing it to be in the horizontal direction, and thereby requiring that the point of the beam have a ***support*** to prevent its sinking too low. This support may be supposed either a *foot*, as seen in many both ancient and modern ploughs, or in the shape of a wheel or wheels, so much employed in many of the English ploughs. We see at once, under this consideration, the office that a wheel performs in the action of a plough. It has been shown, that, whether the plough be drawn in the ordinary direction of draught *b f*, in which one oblique propelling force only is exerted, or with two antagonist forces, *b i*, in the horizontal direction, and the upholding force *b k* in the vertical, we find that, in the vertical, the difference in favour of the motive force is only $\frac{1}{24}$ of the usual resistance; but the upholding force is equal to $\frac{2}{7}$, while none of these variations has produced any change in the absolute resistance of the plough. The impelling force is theoretically less in the latter case; but since the wheel has to carry a load of 95 lb., we have to consider the effect of this load upon a small wheel, arising from friction and the resistance it will encounter by sinking less or more into the subsoil. We have ascertained, from experiment, that the difference of force required to draw a wheel of 12 inches diameter, loaded as above described, and again when unloaded, over a tolerably firm soil, is equal to 22 lb., a quantity

exceeding $1\frac{1}{2}$ times the amount of saving that would accrue by adopting this supposed horizontal draught with a wheel. Having thus found the amount of draught at two extremities of a scale, the one, being the oblique draught, in common use, at an angle of 20°, the other deduced from this through the medium of the established principles of oblique forces, and the oblique force producing a saving of only $\frac{1}{24}$ of the motive force, while it is encumbered with an additional resistance arising from the support or wheel, it necessarily follows that at all intermediate angles of draught, or at any angle whatever, where the principle of the parallelogram of forces finds place—and it will find place in all cases where wheels *yielding any support* are applied to the plough under the beam—there must necessarily be *an increase in the amount of resistance to the motive force.*

780. This being a question of some importance, the diagram, fig. 294, will

Fig. 294.



THE THEORY OF THE DRAUGHT OF WHEEL-PLOUGHS.

render it more evident. Let *a* be the point of resistance of a plough's body, *b* the point of the beam, *c* the position of the horse's shoulder, and *a d* the horizontal line; then will *c a d* be the angle of draught equal to 20°. Let the circle *e* represent a wheel placed under the beam, which is supported by a stem or shears, here represented by the line *e b*. In this position, the point of the beam, which is also the point of draught, lies in the line of draught; the wheel, therefore, bears no load, but is simply in place, and has no effect on the draught; the motive force, therefore, continues to be 336 lb. Suppose now the point of the beam to be raised to *g*, so that the line of draught *g c* may be horizontal; and since the line of draught lies now out of the original line *a b c*, and has assumed that of *a g c* (*g* being now supported on the produced stem *b g* of the wheel), draw *g i* perpendicular to *a c*, and complete the parallelogram *a i g k*; the side *a i* will still represent the original motive force of 336 lb., but, by the change of direction of the line of draught, the required force will now be represented by the diagonal *a g* of the parallelogram, equal to about 351 lb.; and *g c* is a continuation of this force in a horizontal direction. The draught is therefore increased by 15 lb. Complete also the parallelogram *a l g m*, and as the diagonal *a g*—the line of draught last found—is equal to 351 lb., the side *l g* of the parallelogram will represent the vertical pressure of the beam upon the wheel *e*, equal to about 200 lb., which, from experiments (par. 779) may be valued at 40 lb. of additional resistance, making the whole resistance to the motive force 391 lb., and being a total *increase arising from the introduction of a wheel in this position of* 55 lb. Having here derived a maximum—no doubt an extreme case—and the usual angle of 20° as the minimum, we can predicate that, at any angle intermediate to *l a b* and *l a g*, the resistance can never be reduced to the minimum of 336 lb. Hence it follows, as a corollary, that *wheels placed under* *the beam* can never lessen the resistance of the plough; but, on the contrary, must in all cases increase the resistance to the motive force more or less, according to the degree of pressure that is brought upon the wheel, and this will be proportional to the sine of the angle in the resultant $a\ g$ of the line of draught.

781. The application of a *wheel in the heel* of a plough does not come under the same mode of reasoning as that under the beam, the wheel under the heel becoming a part of the body, from which all the natural resistance flows; but in viewing it as a part of that body only, we can arrive at certain conclusions which are quite compatible with careful experiments.

782. The breadth of the whole rubbing surface in the body of a plough, when turning a furrow, is on an average about 17½ inches, and supposing that surface to be pressed nearly equal in all parts, we shall have the *sole-shoe*, which is about 2½ inches broad, occupying ⅐ part of the surface; and taking the entire average resistance of the plough's body, as before, at 336 lb., we have ⅐ of this, equal to 48 lb., as the greatest amount of resistance produced by the sole of the plough. But this is under the supposition that the resistance arises from a uniform degree of friction spread over the whole rubbing surface of the body; while we have seen, on the contrary, that the coulter, when acting alone, presents a resistance equal to the entire plough. It is only reasonable, therefore, in absence of further experiments, to conclude that the fore-parts of the body, —the *coulter* and *share—yield a large proportion of the resistance when turning the furrow-slice;* but since we cannot appreciate this with any degree of exactness, let the sole have its full share of the resistance before stated—namely, 48 lb. If a wheel is applied at or near the heel of the plough, it can only bear up the hind part of the sole, and prevent its ordinary friction, which, at the very utmost, cannot be more than ½ of the entire friction due to the entire sole. A wheel, therefore, placed here, and acting under every favouring circumstance, even to the supposed extinction of its own friction, could not reduce the resistance by more than 24 lb., being the half of that due to the entire sole, or it is $\frac{1}{14}$ of the entire resistance. But we cannot imagine a wheel so placed to continue any length of time, without becoming clogged in all directions, thereby greatly increasing its own friction, seeing the necessarily small portion of any wheel that can be so applied will sink into the subsoil to an extent that will still bring the sole of the plough into contact with the sole of the furrow. It will thus be found that the amount of reduction of the general resistance will be very much abridged, certainly not less than one-half, which reduces the whole saving of draught to a quantity not exceeding 12 lb., and even this will be always doubtful, from the difficulty of keeping such wheels in good working condition. This view of a wheel placed at the heel has been confirmed by actual experiments, carefully conducted, wherein Palmer's patent plough with a wheel in the heel (as patented many years ago—but in this case it was applied on the best principles), gave *indications of increased resistance from the use of the wheel, as compared with the same plough when the wheel was removed;* the difference having been 1½ stone, or 21 lb., in favour of no wheel. We hesitate not, therefore, to say, that in no case can wheels be of service towards reducing the resistance of the plough, whether they be placed before or behind, or in both positions, and the chances are numerous that they shall act injuriously.

783. *Swing and Wheel Ploughs.*—Such may be taken as an exposition of what we deem correct theoretical principles, by which to test the utility or otherwise of wheels as an addition to ploughs. But the vexed question as to which is the best—the wheel or swing plough—is not, we conceive, to be decided simply on

theoretical grounds; considerations of economy and expediency must be taken into account. It seems to be conceded, even by the most energetic advocate of the swing-plough, that the wheel-plough will enable an *inexperienced* workman to perform work of tolerably useful character, while the swing-plough would in his hands be almost entirely useless; again, that while an *experienced* workman has "no great difficulty"—we quote the words of a well-known Scotch agriculturist—"in making straight furrow-slices with swing-ploughs," he has "very great difficulty indeed in making them of uniform depth:" with wheel-ploughs this uniformity of depth is insured.

784. Here, then, we have an obvious distinction between the two forms of ploughs, the swing having more of the character of an implement; the wheel, more of the character of a machine. The distinction here pointed out is important, and should not be lost sight of while attempting to decide which is the best form of plough. Let us pursue the matter a little further. A *machine* operating upon a substance which varies little from its normal condition, may be constructed so as to be nearly in all things self-acting, requiring from man little more attention than is necessary to supply it with the material upon which it is designed to operate. An *implement*, on the contrary, required in an agricultural operation, may, and often does, demand the exercise of skill on the part of the worker to enable it to meet the peculiarities of a soil or crop constantly varying in character. The more completely, therefore, we can make a machine do its own work, and adjust itself to its own requirements, the more completely are we freed from the necessity of employing skilled labour, and the cheaper, consequently, can we do our work. Provided we can get work enough for our machine to do, it is cheaper to construct an expensive machine to do its work with only unskilled, than to employ less perfect mechanism necessitating the employment of skilled labour, which is always found more difficult to be obtained than unskilled. Our manufacturers know the truth of this, and care little for the expense of a machine so that it enables them to employ unskilled labour. The more fully this is carried out, the lower do we find the scale of the wages of the workpeople employed; while the nearer the mechanism obtains the character of an "implement," the wages of the attendant increases.

785. We thus take it for granted, what doubtless will be by all conceded, that the "wheel" possesses more of the characteristics of a machine than the swing-plough; and further, that in many districts—this holding more especially true of England—soils are met with possessing that uniformity of character which best aids the operation of a machine adjusted to do a specific kind of work. Such being the case, it is obvious that the work of ploughing will be more cheaply done when it can be performed by unskilled than by skilled labour; and with such a soil as we here suppose, no one will deny that the work will be as well done as with the swing-plough.

786. We find this consideration enforced very clearly by Mr Handley in his *Essay on Swing and Wheel-Ploughs*. "I cannot but consider," he says, "the fact of the wheel-plough demanding less skill in the ploughman to be a considerable advantage on its side, though it receives but little favour among first-rate swing-ploughmen, who are accustomed to estimate highly their own manual dexterity, from the circumstance of the quality of their work depending on dexterity alone. Undoubtedly there are many men who will make as good work with a swing as with a wheel-plough; but if we take a district (and it need not be a large one) in which a hundred ploughmen are required, it is more than probable that not ten such will be found. This of itself appears to me to be a strong argument in favour of the wheel-ploughs. It has been objected that they

create a nursery of bad ploughmen, inasmuch as it is in the power of any one to make a good furrow with a wheel-plough, while it tests the abilities of a man to produce the same effect with a swing-plough. When, however, it is called to mind that boys can be instructed at an earlier age in the use of the plough, and enabled to come into better earnings than they could do otherwise, as well as that a boy at 10d. per diem wages may benefit his master by making as good work with the one implement as a man at 2s. can execute with the other; and that the advantage shall be obtained of an even furrow throughout the field, rarely effected by a gang of swing-ploughs, with depth, width, and angle of inclination performed with almost mathematical precision, thereby producing an unvarying bed for the seed and a regular edge for the harrows,—the advantage of the wheel-plough can scarcely be estimated too highly, and marks a decided preference."

787. So much, then, for the question of economy with reference to the employment of skilled and unskilled labour. The advocates of wheel-ploughs, however, go further, and point to a wide experience in evidence of economy in *draught*. Mr Handley, whose practical experiments with wheel and swing-ploughs resulted in showing that a diminished force was required by the wheel as compared with the swing-plough, states that it appears to him that this diminished force of draught is "principally, if not fully, explained by the more uniform horizontal motion communicated to the share and sole of the wheel-plough, through the regulating medium of the wheels at the fore part of the beam, which diminish the shocks arising from the continual vibrations of the implement when balanced between the hand of the ploughman and the back and shoulders of the horse. It is not contended that the wheels so situated act the part of lessening the friction between the sole and soil, but they keep the rubbing part more truly to its depth, and maintain its horizontal action more correctly; whereas the horses affect a swing-plough at every step by the irregularity of their proper movement, which has to be counteracted by the effort of the man at the opposite end. Thus conflicting forces are momentarily produced, and continual elevations and depressions of the point of the share take place, together with deviations from the flat position of the sole, which should be retained at right angles to the perpendicular, and to remedy which, unskilful ploughmen bear unequally on the stilts, which produces a lateral pressure landwards, and consequently a great amount of friction along the whole of the left-side plane of the plough. However small may be the efforts of the ploughman to keep his plough 'swimming fair,' those efforts must be attended with increased resistance, and consequently with increased exertion of the horses."

788. We have deemed it right thus to give both sides of the question, not so much with a view to decide which of the two forms of ploughs is best adapted for work, but mainly to show that, as there is a distinct difference of character between them, so there must necessarily be a class of soil in which one is better fitted to do the work than the other. This compromise of opinion, we take it, must be made by the advocates of the two forms. Wherever a soil approaches the character of uniformity (which we have shown is necessary for the operation of a machine), the more closely we can bring this machine to the condition where it is self-adjusting and requires little exercise of mind on the part of its attendant, the more economically, and, *cæteris paribus*, the more perfectly, will it do its work. In such cases the balance of circumstances is in favour of wheel-ploughs. On the other hand, it must be conceded that in some districts, and in Scotland generally, the soil is so crude, unsteady, and unequal, that some exercise of skill and forethought on the part of the attendant is imperatively demanded before

the plough can do its work well: in such cases the balance of circumstances is in favour of the swing-plough.

789. Now, it will be pretty generally admitted that, as a rule, the soil possessing a uniformity of character is more frequently met with in England than it is in Scotland, where the unequal soil is prevalent. May not this circumstance give us somewhat of a clue to the reason why in England wheel-ploughs are such favourites—the swing an equal favourite in Scotland? It certainly seems to us that this is a more philosophical way of accounting for the difference of opinion than that generally received, which attributes it to mere prejudice—one mutually held by English and Scotch agriculturists. Prejudice may sustain its power for some time, but when its maintenance is found to be at the expense of time and money, it soon loses its force and influence. A statement may be here permitted, and one which is pregnant with meaning, namely, that the opinion of Scotch agriculturists, long and almost universally inimical to wheel-ploughs, is fast becoming modified, and that they are being introduced successfully into practice. May not this arise from the circumstance that some soils, through superior culture, have assumed that uniformity of character which enables the wheel-plough to be worked where, in times gone by, it would have been found almost inoperative. Indeed, we may state it without hesitation, that as long as the soil contains a large proportion of loose though even small stones, there the use of the wheel-plough is impracticable, and the swing-plough implement is required to wend its way through them by skill, and not by mere force. On the other hand, smooth soils are just the medium for the exercise of the wheel-plough machine.

790. *Yester Experiments on the Draught of the Plough.*—As the comparatively easy draught of the plough is an essential facility to the quick ploughing of the land, it may interest our readers to learn the method adopted by the Marquess of Tweeddale of reducing the draught of the East-Lothian plough, Plate I. The experiments were conducted in the following manner: Whenever it was attempted to penetrate the soil to the depth of 12 or 14 inches with the East-Lothian plough with four horses, it was found that the strain upon the arms of the ploughman was much more than he could bear, and that the mould-board could not clear itself of the furrow-slice without such an over-strain upon the horses as to endanger the integrity of the harness. It required no dynamometer to indicate the great weight of the draught, it being too plainly indicated by the exhausted state of the men and horses. It was therefore clear that as long as the form of that mould-board was what it is, it would be subjected to an upward pressure from the furrow-slice whenever the plough was wanted to go to the depth of 14 inches into the soil; that the plough was thereby raised towards the surface of the ground, and that the furrow-slice did not fall away of its own gravity from the ear of the mould-board. To obviate these difficulties, it was determined to experiment, and the conjecture was formed that a mould-board convex in front would in the first place clear the furrow-slice, and then allow the plough to go down. A mould-board was accordingly made of wood of a convex form. A model furrow and furrow-slice were at the same time made in the ground with the spade, and the plough with the wooden mould-board fitted into it and worked. Wherever the mould-board was found to be too full, it was cut away; and where too lean, a veneer of wood was nailed upon it. Thus, one modification after another was made in the mould-board by the suggested practical ideas of the farm-steward, ploughman, and carpenters, and each suggested modification was made in the forenoon and tried in practice in the land in the afternoon. When, by a repetition of this process, the wooden mould-board had acquired the shape that gained the end desired, a piece of sheet-lead was beaten upon it to

take a mould of its shape, and from that mould a pattern was constructed, from which a casting was made of an iron mould-board. This method of trial and error is clearly the sound practical way of arriving at results which cannot be attained in any other by theory or deduction.

791. The result of these interesting and now proved to be important experiments has been the forming of a mould-board, as represented in figs. 5 and 6, Plate II., which allows a plough drawn by four horses to go to a depth of 15 inches in any soil with as much ease as any common plough goes to the depth of 10 inches with two horses. Thus originated the "Tweeddale Plough." The secret of its success is, that the mould-board, instead of pressing against the furrow-slice along its entire length, gets quit of it at once by its convex breast, and causes it to slip along in a straight line till it reaches near its ear, where the furrow-slice assumes its proper position by its own gravity. The action of the mould-boards may be easily compared by inspecting figs. 5 and 6 in Plate II., with figs. 1, 2, 3, and 4. Friction of the furrow-slice is thus practically avoided.*

792. A remarkable coincidence of form between the mould-board of the Tweeddale plough and the hull of a ship built on the most recent scientific principles, may here be mentioned. Were a similar section of the mould-board of the Tweeddale plough to that represented in fig. 6, Plate II., added to it on its other side, a section would be produced which would be a *fac-simile* of the transverse section of the hull of the frigate *Vernon*. Thus the form of the easiest-going plough in land has been practically brought to be identical with the scientific form of the hull of the fastest-sailing frigate on the sea.

793. Having considered the power of the horse in its connection with the plough, we shall now turn our attention to that of steam as a substitute.

794. *Steam-Ploughing.*—"Steam-Culture" and "Steam-Ploughing" are terms which, though used synonymously, differ widely in their signification: steam-ploughing is precise and defined, steam-culture is vague and indefinite. Steam-culture may include a variety of implements, or may apply only to one; steam-ploughing refers to one implement only. By steam-ploughing we understand at once that the plough, in its ordinary form, is accepted as the implement best calculated to prepare the soil for the after processes; the term steam-culture, on the contrary, leaves the question an open one as to what really constitutes the best method of preparing the soil. While by no means denying that there may be a method by which the soil will be prepared in a more economical and philosophical manner than that obtainable by the plough, still we think it will be admitted that, with the majority of practical men, the plough is considered the best implement which has yet been introduced, and that for many years to come it will be the only one which will be employed. Certainly, of the many plans proposed to prepare the soil by means other than the plough, none have taken that position which would induce practical men widely to introduce them. The whole question is in a transition state, and the experience of a few years may show that steam-ploughing—that is, applying the power of steam to drag the ordinary plough—is a mere necessity of a particular implement, and that it will be more economical to adapt a new implement to the new power; while, on the other hand, experience may tend to fix the plough more firmly in the estimation of practical men, and prove that what is really wanted is the application of a new power to the old implement. The general adoption of deep culture would necessitate the adoption of steam-power. Taking this view, then, that steam-ploughing is a thing accomplished—apart altogether, however, from the question of commercial success—and that all other methods of cultivation,

* *Yester Deep Land-Culture*, p. 30-2.

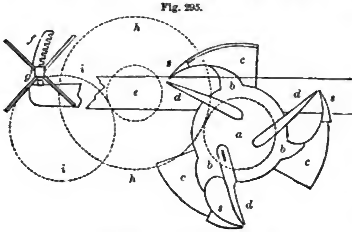
as "rotatory" or "steam digging," are but little removed, if any, from the field of speculation and conjecture, we propose to direct attention to the practical details of those plans of steam-ploughing which have been successful in practice; and the two we take as examples are the plan of the Marquess of Tweeddale and that of Mr John Fowler, C.E.

795. While, however, holding this view, we deem it right briefly to sketch the plans proposed to prepare the soil by "rotatory cultivation," that being the direction in which the majority of those who hold that the plough is not the best implement which can be used, are at present looking.

796. *Rotatory Cultivators.*—In this class of projects the engine passes over the land, working rotatory cultivators—those forming part of the machine. The best known of this class are those of Usher and Romaine, the first of these being earliest in point of date.

797. *Usher's Steam-Plough.*—Mr Usher's machine is generally designated a steam-plough; but although the parts effecting the stirring of the soil are formed like the plough, still their action is rotatory, and partakes little of the peculiar method by which the ordinary plough lays over the furrow-slice at a certain definite angle. We therefore class it as a rotatory cultivator.

Fig. 295.



MECHANISM OF USHER'S STEAM-PLOUGH.

798. The invention consists of two parts: First, the mounting a series of ploughs in the same plane round an axis or shaft, in fig. 295. To this shaft are attached a series of plates or discs, fixed at equal distances. To these the ploughs are attached, the under edge of the mould-board and share of each of which is struck to a curve from the centre of revolution *a*. These ploughs, in revolving, penetrate the soil, and by their mould-boards turn it over. Each of these discs has attached to it three arms or projections, as *b b b*, terminating in the radial direction as shown in the figure from *a*. To these arms the tilling parts are affixed. These consist of the parts *c c c*—acting as the mould-board in the common plough. To the fore-part of the mould-board a wrought-iron bar is affixed, forming a head or share bearer; to this the shares *s s s* are adapted and fixed by its socket. Adjustable coulters *d d d* are affixed in front of each share. By this arrangement each plough in one disc follows successively into action; and the ploughs on the other discs are so arranged that no two of them will come into action at the same moment. The plough-shaft *a* has its bearings at the end of an adjustable or swing-carriage, which vibrates on the centre at *e*, and the extremity of which at *f* is formed into a rack, which is operated upon by a small pinion, worked by the loose handles *g*. In this way the ploughs can be taken up out of contact with the ground at the pleasure of the attendant.

799. The *second* part of the invention consists in applying the power of a steam-engine to give motion to the shaft, with ploughs attached, in such a manner that "the resistance of the earth to the ploughs or instruments as they enter and travel through the earth shall cause the machine to be propelled, thus making the ploughs act in the earth in the same way as paddle-wheels do in the water, by which the vessel is moved along."

800. The movable frame *f e d*, fig. 295, supporting the rotatory ploughs, is

connected with the carriage-frame, which carries the steam-engine and boiler—the former being of the horizontal species. To the front of this carriage-frame a pair of running-wheels are provided; these are mounted in bearings, attached to a horizontal swivel-frame, part of which is provided with a circular rack, into which a pinion works; by turning a handle connected with this, the swivel-frame is turned round in any direction required, and the machine is thus made capable of being turned at the headlands in a comparatively small space.

801. The following are the movements by which the machine progresses, and the rotatory cultivators are worked. To the crank-shaft of the steam-engine a pinion is keyed; this takes into a spur-wheel *h h*, fig. 295, carrying a second pinion *i i*, which again takes into a spur-wheel *e* fixed on the shaft of the cylinder roller, bearing on the soil. By this arrangement a slow progressive motion is given to the machine. The spur-wheel *h h*, taking into a pinion on the shaft *a* of the rotatory cultivator, shown by the dotted lines, gives, at a slightly-increased speed, revolution to the plough-shaft.

802. Although the part of Usher's steam-plough which immediately affects the soil is like the mould-board of the common plough, yet its effect upon the soil is very unlike the action of the plough. Instead of the effect of a mould-board, it is liker the effect of a large sharp hoe passed with much force through the surface-soil to the depth of several inches, scattering it in a dispersed manner immediately behind the machine. From the closeness of the discs, and their consecutive action, friable soil is completely pulverised, and this is the only sort of soil upon which we have seen the machine operate; but upon clay not over-dry we suspect that it will be thrown up into lumps, which will soon harden into clods in dry weather.

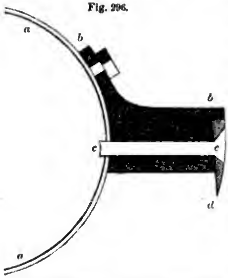
803. *Romaine's Rotatory Cultivator.*—Next in point of date is the rotatory cultivator of Mr Romaine of Canada. The engines are horizontal, and are supported, one on each side of the boiler, by an open framework, between the sides of which the vertical boiler is centrally placed. The framework is supported by two large loose running wheels, the axle of which is bent so as to pass under the boiler; these running-wheels are very broad in the tire. The framework is extended forwards in front of the boiler to a considerable length, and supports at its further extremity a bearing, in which revolves the horizontal shaft of a land-roller, which is used to relieve the framework of a portion of its weight when in action. About midway between the axle of this roller and that of the large running-wheels, the frame is made to extend downwards to provide a bearing for the horizontal axle of the cultivators or cutting implement. The depth to which the cutters operate is simply effected by making the framework vibrate on the axle of the main driving-wheels, and "tipping" it up to any desired elevation by means of a rope and small windlass fixed at the end of the machine opposite to that at which the cutters work.

804. The mechanism for driving the cutters is as follows: On each end of the shaft of the revolving cutter a bevel-wheel is keyed. These are concealed in the open ends of the revolving cylinder, so that this can work quite close to the ground without disturbing the action of the gearing. Smaller bevel-wheels are keyed on to the foot of vertical shafts, to the upper end of which cranks revolving horizontally are keyed, and to which the connecting-rods of the horizontal engines, one at each side of the framing, are connected. The vertical shafts have their bearing in the framing.

805. *A progressive motion is given to the whole machine*, and the cutters are kept well up to their work by the following means: Parallel to the axle of the main running-wheels a shaft is made to revolve in bearings on each side of the

framing. This carries at each end a pulley or rollers made of India-rubber or other elastic material. The length of these pulleys a little exceeds the breadth of the tire of the main running-wheels, and against which they revolve in close contact. The friction of the rollers against the periphery of the running-wheels causes these to revolve and make the machine move forward. The rollers are also capable of revolving in the opposite direction, causing the machine to go backwards, and release the cutters from the soil by the following mechanism: To the vertical shafts a bevel-wheel is keyed horizontally; this takes into a vertical bevel-wheel keyed on to a horizontal shaft, having its bearings in vertical "hangers" fixed to the side-framing. A movable "clutch" is attached to the horizontal shaft, and is provided with a bevel-wheel at one end, and a corresponding one at the other. These take into a bevel-wheel fixed at one end of the shaft bearing the elastic rollers, according as the clutch is moved backwards and forwards. The clutch is operated upon by levers, the handle of which is placed at the front of the machine. This system of driving-gear may be easily disengaged by means of a quick screw-movement, which shall draw the elastic rollers out of contact with the peripheries of the running-wheels. The inventor, in the drawings he has published, has shown a pair of screw-spindles fitted with foot-levers, by means of which the attendant can keep the rollers hard pressed up against the wheels; or, by reversing the screw, can release them altogether.

Fig. 296.



DETAIL OF DIGGING-CYLINDER OF ROMAINE'S CULTIVATOR.

806. The following is a description of the digging apparatus: The shaft carries a cylinder, part of which, *a a*, fig. 296, is shown, provided with a set of radiating arms *b b*, *c c*, to which the knives or cutters *d* are attached. These arms are set at equal distances apart upon the cylinder, and the knives or bars are screwed or riveted to their outer ends. Fig. 297 gives a transverse section of the cutting-knives or bars. The edges of these bars, which may be either plain or serrated, are so set, that on the revolution of the cylinder they are the most favourably disposed for entering and cutting the ground; and they are made either parallel with the axle, or set spirally or inclined thereto; or the bars may be formed of double angular lengths, so as to present points and angular surfaces during working. Curved picks may also be attached to the digging cylinder.

Fig. 297.

CUTTING-KNIFE OF ROMAINE'S CULTIVATOR.

807. It may interest our readers to know that this machine is the one aided by funds voted by the Canadian Legislature, which is "taking the lead in promoting cultivation by steam." Mr Romaine fully anticipated a public display of the powers of the apparatus at the Agricultural Exhibition at Paris in 1856, but a variety of difficulties which arose in perfecting its details prevented this. Mr J. Evelyn Denison, M.P., who, at the request of our Government, drew up a Report of the Exhibition, thus speaks of the machine: "Still it is just to Mr Romaine that I should bear testimony to what I saw, and to the point which he had attained. I saw, in a field near Paris, Mr Romaine's machine, carrying its own boiler and engine, travel by its own locomotive power 100 yards up one field, and break up and cultivate the land in its course." The manufacture of this machine has been taken up by Mr Crosskill of Beverley, and a recent trial of one manu-

factured by him has been attended, according to a newspaper report, with satisfactory results.

808. *Heathcoat's Steam-Plough.*—First in point of date is the Steam-Plough of John Heathcoat, Esq., M.P., introduced in 1833, specially for the reclamation of bogs or mosses, a species of soil offering, perhaps, the greatest natural obstacles to improvement by mechanical means. The machine embraced three distinct parts —(1) the steam-engine, and mechanism capable of moving along the field; (2) the two auxiliary carriages, placed at the distance of 220 yards on either side of the steam-engine, and each of which is capable of being moved along the field in a direction parallel to the line of movement of the steam-engine; (3) the ploughs, which traverse between the steam-engine and auxiliary carriages. In fields of limited dimensions only one plough and one auxiliary carriage is used.

809. For the matter of the following description of the parts of mechanism and the method of ploughing, we are indebted to an article in the *Transactions of the Highland and Agricultural Society*, vol. xii. p. 75: "The parts forming the medium of locomotion consisted of two pairs of skeleton drums, one placed at each end of the apparatus. These pair of drums were 26 feet apart, and are 9 or 10 feet in diameter. Their position resembled that of the wheels of a four-wheeled waggon. They were formed individually by the combination of three wheels of equal diameter, placed parallel to each other, and connected by a common axle. The two drums on each side of the machine, being one of each pair, were embraced by a great endless band of about 7½ feet in breadth, composed of planks and iron hoops so arranged as to form a flexible driving-band. The axles of the drums were supported in the extremities of a strong frame, which was again supported by a number of small friction-rollers upon the lower part of the great bands. These wheels or friction-rollers were arranged in rows, so placed that they fell upon the lines of hoop, while at the same time they turned upon axles fixed to the frame or platform, and thus afforded an easy smooth motion to the platform, even when loaded with its machinery. In this manner the great bands formed a perfectly portable and smooth road for the platform, so that whatever was the onward velocity of the whole apparatus, the continually succeeding parts of the bands laid themselves down under and before the foremost drums; while the bands, with their broad surface on the moss, gave an evident stability to the whole. On the platform thus described, the steam-engine with all its appliances was placed. The engine resembled an ordinary locomotive of the period, the speed being reduced to the necessary rate by a combination of gearing which branched off to each side of the engine, and ended in a large spur-wheel fixed on the axle of each of the drums situated towards the left of the machine. Another branch of gearing was led off to each side of the engine to give motion to a set of pulleys. On these pulleys the flat iron band was coiled which dragged the ploughs. The auxiliary carriages already adverted to were furnished with the requisite gearing, by which they could be moved forward as desired. Each carriage was also furnished with a plain pulley, round which the flat band above alluded to was passed. This band proceeded from and returned to the principal machine, and was coiled by the power of the engine round the pulley thereto attached. The plough was connected with the band. Each of the carriages moved upon two lines of planks, one line being laid on the natural surface of the moss, the other, to resist the drag of the plough, was laid in a shallow trench cut in it. Three lengths of plank were all that were necessary, the one behind being brought up and laid in before the others in regular succession as the work proceeded. The plough was double—that is, had two sets of stilts, one set at each end, and each set had four handles,

it being found necessary sometimes to employ two men to guide the plough. There were also two shares, coulters, and mould-boards; these being both on one side, set tail to tail. The plough acted to and from the machine without turning round. The form of the mould-boards was such that the furrow-slice was laid completely over, with its heath surface downwards.

810. "The auxiliary carriages, as before mentioned, moved in lines parallel to the roadway of the principal machine, and at a distance of 220 yards therefrom. The flat iron bands, each of 660 yards in length, passed out from each side of the machine, where the ends were secured to one of the machine pulleys on the respective sides; they were then passed round the large pulleys of the carriages, and returned to the machine. At this point the plough was attached to the band, while as much more band was coiled round the other machine pulleys respectively as was equal in length to the distance between the machine and the carriages. The steam-engine being put in motion, the action was as follows: The second branch of gearing was adjusted to act upon the pulley, to which the end of first band was attached; this pulley coiled up the band, caused the plough to advance towards the carriage at the same time the other pulley, which was free to uncoil, delivered off its portion of band. When the plough reached the auxiliary, the motion was stopped, the plough was set to the next furrow; the action of the steam-engine on the pulleys was changed by shifting a clutch from the one to the other; and the pulleys reversed their duty, that which had been uncoiling now being the coiler, and so on alternately."

811. The machine and its auxiliaries had, according to the statement of the inventor, to be moved only 11 yards for every $5\frac{1}{2}$ miles travelled by the plough, and for every statute acre worked. The principal machine weighed, with a six-ton load of fuel, about 30 tons; it had a superficial bearing of 390 square feet, and exercised a pressure of 178 lb. on each square foot of moss. This buoyancy would have enabled it to have traversed much softer soil than flow-moss. The two steam-engines had cylinders of 10 inches diameter and 24 inches stroke, making 60 strokes per minute. The machine travelled 1 inch for every stroke of the engine—the pressure to allow this velocity being 4 lb. on the inch. The flat iron band used for dragging the plough was $2\frac{1}{8}$ inches broad and $\frac{1}{16}$ of an inch thick. The friction of the band with the empty plough required a pressure of 8 lb. to overcome it; but when the plough had hold of the furrow-slice, the pressure required was 13 lb. The force required to work one plough, moving at the rate of two miles an hour, turning over a furrow-slice 18 inches by 9 inches, was equal to fifteen horses. From $1\frac{1}{2}$ to 2 tons of coal were consumed per day.

812. The weight of the plough was $12\frac{1}{2}$ cwt. The number of men required to work the plough was as follows: two to conduct a plough, one to attend to the movement of the auxiliary carriage, and one to prepare the end of the furrow next to the machine for the entrance of the plough in the succeeding *bout*. The full complement of men for two ploughs was reckoned at eight labourers, one engine-man, and a boy to assist at the machine. Although this machine "proved itself," in the words of the report, "in ploughing wet bog-land," for some cause or other it was not carried practically out, and is now superseded by other arrangements more perfect in mechanical details.

813. *Lord Willoughby d'Eresby's Steam-Plough.*—We have now to notice the steam-plough introduced by Lord Willoughby d'Eresby. In general arrangement, and in its principle of working, the plan resembles somewhat that of Mr Heathcoat's, just described, with this difference, that in place of the engine-and-pulley mechanism being placed in the centre of the field, with an auxiliary

carriage on one side, or on each side of it, two engines are used, one placed at each side of the field, a double plough working parallel to each other being drawn from and to each engine, two furrow-slices being turned over at the same time. Each engine is provided with a capstan or chain-barrel, *on* which the chain is wound, and *from* which it is unwound alternately. Only one engine, therefore, is occupied in hauling the ploughs across the fields, winding up on its barrel the chain to which the ploughs are attached; the other end of the chain, attached to the non-working end of the plough-frame, being at the same time unwound from the capstan of the opposite engine. Each engine as it is alternately at rest—so far as working the plough is concerned—is moved along a tramway of planks. There are also two sets of ploughs in the frame, one at each end, and looking in opposite directions, each set being easily lifted up out of contact with the ground by means of racks and pinions. By this arrangement the necessity for turning the ploughs is obviated; they are simply moved along the field a distance equal to the width of two furrows, where the one set which has just finished the furrows is lifted up, while the other set is placed in contact with the ground. The engine in the opposite side of the field is then put to work, when the ploughs are drawn across the field. The double plough in the centre of the frame has shares at both ends, the mould-board being fixed on a bearing, so that it can be turned to suit the direction in which the plough is going. The wheels on which the plough-frame runs are easily adjusted to suit the depth of ploughing.

814. The plough is capable of ploughing two 9-inch-deep furrows, 163 yards long, in two minutes, or, allowing for shifting forward and altering the position of the plough, gives five minutes for the double journey. This rate gives 4 acres a-day as the result. The cylinders are 8 inches diameter and 12 inches stroke, and the engines make 120 revolutions per minute. The pressure required is 40 lb. to the inch.

815. *The Marquess of Tweeddale's Steam-Plough.*—We now proceed to consider the two plans which we have selected as examples of the present position of the question of steam-ploughing, the first of which is that of the Marquess of Tweeddale, and the second that of Mr Fowler. Although the extent and the practical value of the Marquess's labours have not been so widely known, or so fully appreciated by those who have been aware of them, as they undoubtedly deserve to be, no one has contributed so much towards the practical solution of the question of steam-ploughing as this nobleman. We are glad, therefore, to avail ourselves of this opportunity to express our deep sense of the obligation under which the agricultural world lies to the Marquess, for the time, research, and large pecuniary expenditure he has devoted to this most important point of agricultural economics.

816. In commencing his experiments on steam-ploughing, the Marquess soon became satisfied, that before working the land with steam-power, whether by ploughing or digging, it would be necessary to loosen the soil and subsoil, and to reduce them to a state of pulverisation, at the same time to remove all set-fast stones and other impediments, so that the machinery of the steam-engine and the ploughs or digging-apparatus should not be subject to any sudden concussion.

817. To insure this, the first step taken was to plough the land as deep as one set of four horses yoked to a plough, and another set of four horses yoked to a subsoil-plough, would enable to be done, the depth the land being stirred to an average of 19 or 20 inches, and all stones being removed which were found within that depth. (See fig. 272.)

818. With reference to this preliminary operation, the Marquess states that the more he investigates the subject, the more fully is he convinced of its necessity. The soil should be rendered as friable as possible, and every impediment removed which would check the speed at which the engine can work. We are well aware that this will by many be objected to, as involving unnecessary labour; but it will be obvious on consideration that the more uniform in character we can obtain the material upon which any machine we employ is to operate, the more uniform will be the result, and by consequence the more economically and certainly will it be obtained. Take, for instance, the various processes involved in the manufacture of cotton. No objection is made by the manufacturer to the preliminary processes by which the material is prepared to undergo the finishing operations. On the contrary, every exertion is made to secure mechanism by which these can be best accomplished, manufacturers being well aware that the more completely what is called the "preparation" is effected, the more satisfactory will be the after process, or "spinning." It would be, to say the least of it, a roundabout way of proceeding to take the crude cotton and spin it as best they could, and thereafter have machines to rectify all the defects brought about by want of attention to those preliminary processes calculated to bring the material into the best condition fitted for the final ones. And yet something of this sort is done every day in farming. We see processes carried on at great expense of time and trouble, and complicated mechanism to aid them withal, which are in fact the mere necessities of an unphilosophical mode of culture, that neglects the preliminary process which, if effected, would leave the soil in the condition best calculated to produce the crop, and obviate all necessity for after proceedings; these after proceedings being in fact simply attempts to get rid of peculiarities which could have been prevented more quickly and certainly at the first. It is in truth a much more reasonable way to prevent weeds from growing, than to invent and use an elaborate machine to pluck them up when grown; to pick out boulders from the path of a steam-plough than to spend time and money in repairs of accidents which their presence has brought about, or to stop the progress of the machine till the impediment has been removed. It is by far the most philosophical way, as it certainly would be the most economical, to bring the material on which any machine is to operate to that condition which will enable the machine to perform its work with as little variation as possible. The more any piece of agricultural mechanism departs from the character of an implement and approaches to that of a machine, the greater is the necessity for the preparation of the material. A close investigation of the agricultural inventions of some years back has shown us that more, or at least as much, attention has been paid to the bringing out of what may be called "preventive" than "preparative" mechanism.

819. To return to the description of the Marquess of Tweeddale's system of steam-ploughing, after this, we hope, not altogether useless digression. After fully considering the three methods of preparing the land—(1) by means of mechanism calculated to dig the land spade fashion; (2) that of rotatory motion; and (3) by the plough—the Marquess decided upon the latter as the best calculated for the work to be done. To suit this implement, however, to the new power to be employed in its traction, important alterations were made in the form of the mould-board. (See par. 703, and Plate II., fig. 8, on the Tweeddale plough.)

820. The next consideration was, whether the engine should move over the land to be cultivated, and drag the plough after it, or whether two engines should remain stationary, one on each side of the land to be ploughed, having a wire rope to draw the ploughs from the one engine to the other. The wear and tear

of the rope dragging on the ground was considered, and the expense of replenishing it calculated, as also the power required to drag the rope either on pulleys or subject to the friction on the rough land. The result of these considerations and calculations was in favour of allowing the rope to be drawn along the ground, the power required to do which was found to be that of one horse.

821. This mode of traction was preferred in consequence of so much power being required to propel the engine itself over the different conditions of soil to be cultivated, and obviating that poaching of the soil which the wheels of the engine would bring about, especially when the soil was not thoroughly dry. Indeed, it is evident that in plans where the engine passes over the land to be ploughed, whether provided with the endless railway or not, the great advantage of steam-ploughing is lost—namely, the prevention of consolidation.

822. In some conditions of the atmosphere, and in some positions where the engine was at work, delay was caused by failing to keep up the full amount of the power necessary to perform the work required. To obviate this, two engines were employed; when the one was working, the other was getting up the steam and pumping water into the boilers. This arrangement enabled smaller boilers to be employed, and the weight of the engines to be greatly reduced.

823. Much consideration was given to various modes of using a capstan anchored on the side of the field opposite to the engine which performed the work, also to diminish the friction by allowing the rope to run on pulleys placed on movable frames. All the appliances of this nature experimented on were found to cause either additional labour or loss of time, so they were ultimately set aside. Another plan was frequently recommended, namely, to give the drag-rope the velocity used in the circular saw: it was thought that by this means the weight of the rope would be reduced, and additional speed given to the ploughs. This principle did not appear to the Marquess to be applicable to steam-ploughing, as the length of the rope moving over the pulleys would cause great additional expense in replacing by manual labour the number of pulleys necessary to preserve the rapid motion contemplated.

824. The first attempt to plough by steam-power was with a single plough taking a furrow 15 inches deep by 14 broad. The power of the engines was soon found competent to drag two ploughs capable of making two furrows of the above-named depth and breadth. The engines were of 14-horse power each; they propelled themselves on the roads in the neighbourhood at the rate of 4 miles an hour, and at this rate they could ascend rising ground of 1 in 11. When they were working in a field, they travelled on movable rails, which were removed to the front as soon as the engine passed over them. Though the winding drums of the engines were so constructed as to give way to any impediment that would injure the machinery by resistance, the precaution became unnecessary from the pulverised state of the soil.

825. The engines had two speeds, the one 3½ miles, the other 5 miles an hour. When in working trim, with a full supply of water and coke, they weighed 8 tons each, and it required them to weigh as much on a broad gauge, to enable them to give sufficient resistance to the drag of the plough. Where the engines are lighter, they must be anchored to afford this resistance.

826. On first commencing operations, the Marquess ploughed with a deep and wide furrow. No statistical information is now obtainable showing the ratio of the increase of power with that of depth, commencing at 6 inches, and ending at 15, increasing an inch at each time. The Marquess, however, is satisfied that the increase of power required must not be measured by arithmetical proportions—so much so, that he states that he would undertake to plough 70 inches

broad and 8 inches deep with less money than 28 inches broad by 15 inches deep, which is a ratio of 4 to 3 in favour of shallow ploughing as regards expense. Where the preliminary process of pulverising the soil is gone through, the Marquess states that he would not plough deeper than 8 or 10 inches at most, as it is only the surface that becomes hard and crusted, while the soil below remains quite tender.

827. The following is a description of the working of the ploughs in the frame contrived for that purpose: When the ploughs are working, the two left-hand wheels travel on the unploughed land—the right-hand wheel in front, which guides the frame, goes in the furrows, and regulates the operation of ploughing, both as to depth and breadth of furrows; the hind wheel on the right side is raised above the frame so as not to press on the right-hand furrow-slice just turned. To prevent any delay in the ploughs returning to the other side of the field and making a contiguous furrow, there are two sets of ploughs, one set above the other, with right and left-hand mould-boards attached to the frame by an axle, and on which they are turned to suit the following furrow, in the form of a turn-wrist plough, but with the mould-boards looking different ways. (Compare fig. 277 with fig. 1, Plate VII). On the plough coming close to the engine, the frame is raised by the engine on a crank shaft; this is attached to a beam projecting from the engine, high enough to allow the plough to turn on the axle. The ploughs are then lowered by the turning of the crank-shaft—the throw of which is equal to the breadth of two furrows—into the exact position for commencing the return furrow. After this operation is concluded, the steam-engine is moved forward 56 inches—that is, the width of four furrows of 14 inches each, and a signal is made to the engine-driver at the other side of the field to start the engine and draw the plough across. This operation at each end of the furrows is performed as quickly as a ploughman could turn a pair of horses in the ordinary mode of ploughing.

828. In Plate VII. we give illustrations of the steam-engine and plough-carriage—fig. 1 being in elevation, and fig. 2 a plan. The engine consists of a tubular boiler at *a*, fig. 2, with a cylinder *b b*, one on each side, driving a cross-shaft *c* at the end of the boiler. This shaft is connected by mitre-wheels with a longitudinal one *d*. This shaft carries two loose spur-pinions of unequal sizes. Between those a sliding clutch *e* is placed, by means of which either of the spur-wheels can be connected with the shaft. Below the shaft *d* another is placed which carries the winding-barrel *c*, fig. 1; a wheel is keyed on at each end of the shaft, and gears into one of the pinions on the shaft *d*, fig. 2. According as the small or large pinion on the shaft *d* gears with the spur-wheel on the barrel-shaft, is the speed of the latter fast or slow. A wire-rope is wound or unwound on the barrel *c*, fig. 1, according to the direction in which it is made to revolve. The power of the engine is used to make the apparatus locomotive, as follows: On the crank-shaft a mitre-wheel is fixed, which takes into another wheel fixed on the main driving-axle of the engine-carriage. A clutch is used to place these wheels in and out of gear as required. The barrel *c*, fig. 1, is not permanently fixed on its shaft, but can be disengaged from it when necessary. This is done when the bevel-wheels above mentioned are in gear, and the power of the engine working the carriage. When it is wished to work the barrel, and the engine to be stationary, the bevel-wheels are thrown out of gear, and the barrel fixed in its shaft. By this arrangement, when the engine is working the carriage wheels, the barrel is stationary, and *vice versâ*. The bearing or carriage wheels are broad in their periphery or tire, and rest on temporary wooden rails or planks to prevent them sinking into the ground when working. When the engine is travelling on ordinary roads, it is

guided by means of the front wheels, which are smaller in diameter than the others; these are fitted to a swivel-carriage provided with a segmental toothed rack. A pinion fixed to a vertical spindle, provided with a cross handle at top, gears with the teeth of this rack, and as the cross handle is moved from right to left, the segmental rack and swivel carriage is moved correspondingly.

829. *The plough-carriage* consists of two main bars *g g*, fig. 2, connected at the ends by cross pieces, and intermediately by two stretchers or distance-pieces. These are adjustable, so that the distance between them can be varied according to the breadth of the furrow-slice. The cross ends of the frame move in gudgeons or journals, in cast-iron blocks or beams, pedestals fixed to the bars *h h*. The frame can thus be turned upside-down when required, it being held in any position by a small catch at each end, and connected with the axle-bars. The carriage is supported by four wheels; those on the land-side have short axles fixed by pinching-screws to the upturned ends of the axle-bars *h h*. Of the two on the furrow-side a peculiar adjustment is necessary, inasmuch as the one which goes first in the bottom of the furrow, while the plough is going in one direction, runs on the ploughed land when the plough is going in the opposite direction, and becomes the last; the other wheel, which was previously the land, now becoming the furrow-wheel. To effect this change in the relative position of the wheels, the following arrangement is adopted: Near the end of the axle-bars *h h*, fig. 2, a crank is fitted, the pin of which projects sufficiently to carry the bearing-wheel. This crank is allowed to make a half revolution only, on the axle-bar, a block or projecting stop being so fixed as to stop it when it arrives at the highest and lowest points. The bearing-wheel on the pin of the crank has attached to its eye a pinion which gears into a wheel keyed on to the bar *h*. At the upper and lower ends of its diameter a few teeth are removed from the wheel. The parts thus deprived of teeth correspond to the high and low position of the crank; so that, when the pinion or the eye of the bearing-wheel by the half revolution of the crank is placed in either the high or low position, it is at liberty to revolve without coming in contact with the teeth of the wheel. When the crank is in its low position, the bearing-wheel is running in the bottom of the furrow-slice; but when in this position the toothed wheel is caused to revolve, and at the same time the crank moved a little out of the vertical position, the teeth of the pinion catch those of the wheel, and cause it, as it were, to climb round it. When the crank reaches its high position, the block or stop arrests its movement, and the teeth of the pinion coming, at the same time, to that part of the wheel deprived of teeth, it is free to revolve. The bearing-wheel is thus raised from a low position in the furrow to a high position on the land. In lowering the wheel, the reverse of the movement above described takes place; the forced revolution of the carriage-wheel and its pinion, by contact with the toothed wheel, checking its otherwise rapid descent.

830. *The two pairs of ploughs* *i i*, *j j*, of complete plough-bodies, are mounted on the main bars *g g*. The two which act when the carriage is moved in one direction are marked in fig. 2, Plate VII., by the letters *i i*; those which act while the carriage is moved in the opposite direction being marked by the letters *j j*. These two sets of ploughs are made to work to opposite sides, one set throwing the furrow to the right and the other to the left side; in this way all furrow-slices are made to lie over in one direction. When the plough-frame reaches one end of the open furrow, the furrow-wheel runs up a light inclined plane made of wood, and which is placed near the engine; the ploughs are thus lifted out of the soil, the engine is stopped, and the plough-frame reversed, to bring the other set of ploughs into action. The other engine on the opposite

side of the field is then put in motion, and the plough-carriage is dragged across the field. When the double journey is thus completed, the carriage requires to be moved along the field at the headlands a space equal to the breadth of two furrows.

831. This lateral movement of the plough-carriage along the field is effected in a very simple manner, thus: A beam *f f f*, fig. 1, is permanently fixed overhead to the engine-frame, and extends at right angles to it a distance equal to the extreme length of the plough-carriage. Its outer end is temporarily supported during the operation of lifting the ploughs by a light wooden pole *g*, which catches on a pin on the end of the beam. This beam *f f f* carries brackets or hangers, in which a shaft *e e* works; to this a screw-wheel *d* is keyed, which is arched in by an endless screw on the light shaft *o*, fig. 2. This shaft *o* is driven, when required, by clutched gearing from the shaft *d*. Two cranks *p p*, fig. 1, are fitted to the shaft *e*, and have suspended to their extremities forked chains, which are attached to the two ends of the plough-carriage. The throw of the cranks *p p* is equal to the breadth of two furrows, that is, from 24 to 28 inches, according to the breadth of the furrow-slice. At the completion of the double journey, when the carriage is required to be moved, the suspending-chains are attached, and the shaft *e* made to revolve, and the cranks *p p*, making half a revolution, lift the carriage through a space equal to the breadth of two furrows, as required.

832. In working this steam-plough no exact account was kept of the coals consumed, but every one acquainted with the duty performed by steam-engines can easily estimate this particular.

833. Two men were required at each engine, and another man to follow the plough to assist at the turnings at the ends of the landings, but the plough itself required no guidance.

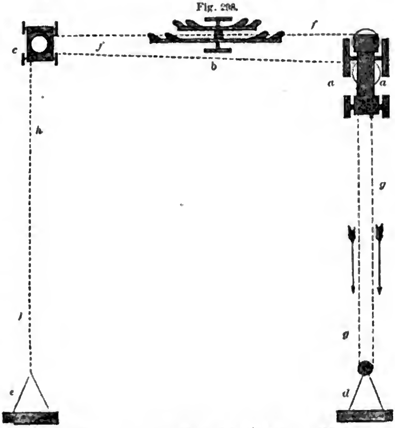
834. The work actually done was this: The length of the rope was 350 yards, and the two ploughs turning over a breadth of furrow of 28 inches, and turning at the land's end, sometimes in a minute, but say in two minutes, and going at the minimum rate of 3½ miles per hour, there were 5½ imperial acres ploughed in ten hours, 14 and 15 inches deep, in a soft clayey soil. The ploughs could travel 5 miles per hour if required, and could thus have ploughed fully 7½ acres in ten hours.

835. *Fowler's Steam-Plough.*—We now notice the second kind of steam-plough, that of Mr John Fowler, who has paid much attention to, and devoted a large expenditure of money on, this department of agricultural mechanism.

836. The diagram in fig. 298 will illustrate the disposition of the machinery used in Mr Fowler's plan, and the mode of operation. The engine and windlass combined are placed at *a a*, and moved along the field in the direction of the arrows as the ploughing progresses. There are two drums or windlasses worked by the engine, which alternately wind up the rope which works the plough *b*; while one is being driven by the engine, the other runs free, and is giving out its rope. The rope passes round a pulley or sheave in the anchor *c*. The fixed anchor and snatch-block are at *d*, and serve as a point of resistance by which the engine winds itself forward. The self-adjusting anchor *c* is placed opposite the engine *a a*, at the extremity of the furrow-line. This is moved along the field coincidently with the engine *a a* as the ploughing progresses. This movement or self-adjustment of the anchor *c* is a recent improvement, and is effected by the passing of the wire-rope *f f* over the drum of the anchor, working, by means of a worm-wheel and screw, a barrel, round which a second wire-rope *h h* is coiled, the end of this being fixed in the anchor *e* to afford a

point of resistance. This wire-rope *h h* is slackened out by the attendant—as each bout is performed—a length equal to the breadth of 4 furrows: this rope is gradually taken up by the drum of the anchor *c* bringing it nearer to the anchor *e*. The anchor *c* is mounted on sharp-edged discs or wheels, which slowly cut their way along the ground. The plough-carriage *b* traverses the space between the engine *a a* and the movable anchor *c*. The whole arrangement forms a parallelogram, the breadth of which is equal to the distance between the engine and anchor *c*, which are placed on the headlands, and the length equal to the distance between the engine *a a* and the fixed anchor *d*. The wire-rope *f f* is prevented from dragging on the land, by being passed over a series of grooved pulleys or wheels, placed at intervals along the line of draught. Each wheel is supported in a light wooden frame with handles, and as the plough-carriage *b* approaches a frame, a boy removes it out of its path, and, after the plough has passed, places the return rope, which is attached to the hinder end of the plough-frame, on the wheel or pulley. On the plough-frame reaching the headland, it is moved a little beyond the end of the furrow and tilted up, thus taking the ploughs which have been last in action out of the soil, and placing the others in contact with it. The engine *a a* and anchor *c* have at this point moved along the field in the direction of the arrows, a distance equal to one breadth of four furrows. The wire-rope *f f* being already placed on the pulleys of the light wooden frames above mentioned, the engine starts. The drum which previously was giving out the wire-rope winds it up, and the plough-carriage is drawn across the field. Eight furrow-slices have thus been turned over in two journeys of the plough-frame *b*.

Fig. 298.

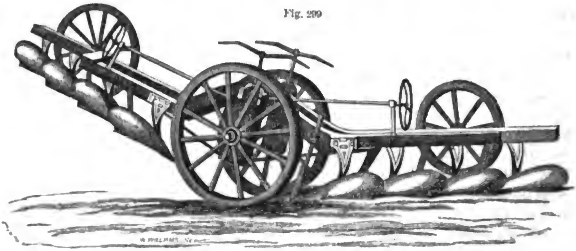


DISTRIBUTION OF APPARATUS OF FOWLER'S STEAM-PLOUGH—SCALE, 20 FEET TO THE INCH

837. *The plough*, of which we give in fig. 299 a perspective view, and in Plate VIII. a plan, fig. 2, and elevation, fig. 1, consists of a series of mould-boards *a a a*, shares *b b*, and *d d* the coulters, carried on the beams *c c*. These beams are curved, as shown in fig. 1, so that when the mould-boards attached to one beam are in action, those attached to the other are at some distance above the ground. The beam is mounted at its centre on an axle carrying two wheels *e f*, one of which, *e*, runs in the furrow, the other, *f*, on the land: two smaller wheels are at *g g*. The plough is steered when at work by the wheels *h h*, which act through the medium of levers *i i i i*; and an endless screw on the lever *j*, shown in dotted lines in fig. 2, which is fixed at *j* to the centre of the axle of the two wheels *e f*. The turning of the wheel *h* carries the lever *j*, and with it the axle of the two wheels *e f*, from right to left, or from left to right, as desired. The attendant, while steering, sits on the seat *l*. The depth

to which the shares cut is regulated by the land and furrow wheels *e* and *f*, which are capable of vertical adjustment by the handles *k k*, fixed to vertical screws, the lower extremities of which work in the bearings of the axle of the two

Fig. 299



FOWLER'S STEAM-PLOUGH CARRIAGE IN PERSPECTIVE.

wheels *e* and *f*. As the screws are made to rise or fall by turning the handles *k k*, they raise or depress the bearings of the axle of the two wheels correspondingly.

838. Of the *engine and windlasses* attached we give an elevation, fig. 1, and a plan, fig. 2, in Plate IX. The engine, in its general construction, is similar to an ordinary portable engine. There are two drums, *a a*, *b b*, placed below the boiler, and as near the ground as possible. These drums alternately wind and unwind the wire-rope which drags the plough across the field. While one is winding up the rope the other is paying out, the rope passing round the sheave or pulley in the movable anchor *c*, fig. 298, and attached to the end of the plough-carriage opposite to that to which the dragging-rope is connected. Motion is alternately given to the drums *a a*, *b b*, Plate IX., by mechanism, as follows: Through the medium of the bevel-gearing *c d*, fig. 2, which is driven by the crank-shaft of the engine, motion is given to a vertical shaft *e e*, fig, 1, to the lower extremity of which a pinion *f* is keyed. To the lower extremity of the vertical shaft *e*, as a centre, a swing-lever *i i*, fig. 2, is connected, capable of being moved from right to left, or *vice versâ*, by the attendant standing on the firing platform of the engine 2, through the medium of the hand-lever *o o*. This swing-lever *i i*, fig. 2, which works horizontally, affords a bearing for a carrier-wheel *f*, fig. 2, which gears into the pinion *d d*. To the upper side of the drums *a b* spur-wheels *g g*, *h h*, fig. 1, are fixed. When the swing-lever *i i*, fig. 2, is placed at right angles to the side of the engine, the carrier-wheel *f* works freely in the space between the two spur-wheels on the drums *a b*, as shown by the dotted lines in fig. 2; but when the swing-lever *i i*, fig. 2, is moved by the handle *o o*, fig. 1, either to the right or left, its extremity embracing and working round on the vertical shaft *e e*, fig. 1, as a centre, the carrier-wheel *f* gears either with the spur-wheel of the left or the right-hand drum, leaving the other drum free to rotate on its axis. Whatever be the position of the swing-lever *i i*, fig. 1, the carrier-wheel *f*, fig. 2, always gears with the pinion *d*, which receives its motion directly from the engine.

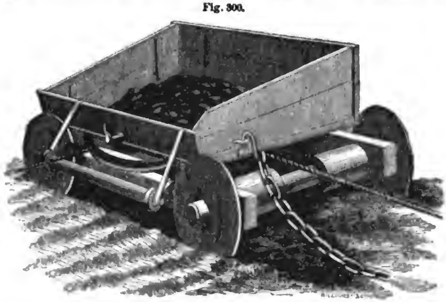
839. The engine is also furnished with gearing, by means of which it can be made to traverse slowly along the field as the plough gradually works across it. The wire-rope *g g*, fig. 298, is wound upon the drum or barrel *m m*, Plate IX., this receiving motion as follows:—To the vertical shaft *e e*, fig. 1, an eccentric,

i, is keyed on; the extremity of the eccentric rod *j j* is jointed to the upper end of a lever *k*, which works on a stud at its lower extremity. As will be seen from the plan, fig. 2, this lever is double, and carries a cross-head, having clicks, which take into notched teeth made on the peripheries of the flanges of the drum *m m*. As the eccentric rod works to and fro, the clicks take into the teeth of the drum-flanges which work the drum slowly round. This apparatus is capable of being thrown in and out of gear by the handle *n*.

840. In addition to the apparatus above described, the engine is furnished with gearing to enable it to travel on common roads. This consists of a pinion, *o o*, fig. 2, keyed on the crank-shaft of the engine *x x*. This pinion engages the spur-wheel *p p*, which is made in one with the pinion *q*, the shaft of these being supported by a stud on the side of the boiler. The pinion *q* engages the spur-wheel *r*, which can be connected or disconnected at pleasure with the road-wheel *v*. The whole system of wheels can be thrown out of gear, when locomotion is not required, by the handle *t* actuating the clutch *s*.

841. The self-adjusting locomotive anchor (*c* in plan, fig. 298) is shown in perspective in fig. 300, and in side elevation in fig. 2; in end elevation fig. 3, and in plan fig. 1, in Plate X. The anchor consists of a box of wood or species of truck *a a* mounted on two wooden rollers *b b*, the axes of which are furnished at each end with discs of plate-iron *c*; *d* is the pulley round which the winding rope passes, being one of the road-wheels on which the anchor is mounted when it is required to be moved from place to place. The motion of the pulley is made to draw, by means as described in par. 836, the anchor along the headland, so as to keep it constantly in the line of furrows opposite the engine. The box or body of the truck *a* is kept loaded with earth, so as to press the discs *c* into the ground, in order to give sufficient resistance to the strain on the snatch-block. As the anchor is drawn along the headland, the discs cut themselves into the ground to the requisite depth. The wire rope, as it works the plough, passes over the friction pulley *e e*.

Fig. 300.



SELF-ADJUSTING ANCHOR OF FOWLER'S STEAM-PLOUGH IN PERSPECTIVE

842. We here present our readers with some suggestive remarks, kindly furnished to us by Mr Fowler, on the economy of steam cultivation as compared with horse: "In our experiments we have used engines of from eight to ten horse-power—that is, marketable horse-power, giving off more than double the horse-power they are sold by. The first thing to be ascertained was the speed at which the plough should travel, as of course the higher the speed the less the strain upon the tackle; and our experience has shown that a speed of about 300 feet per minute, or something less than 3½ miles per hour, is about the best speed for general purposes. At this pace every effective horse-power gives off 110 lb., say 1 cwt. draught. When we consider that in ploughing the different classes of land a draught of from 2 cwt., as in Norfolk, up to 8 and even 10 cwt.

in the clay land of Kent, is required for each furrow, it will be seen that it is impossible to form deductions from the mere fact of ploughing an acre of land; but assuming what experience has proved, that a horse in good condition will travel the eleven miles required to plough one acre, giving off a draught varying from $1\frac{3}{4}$ to 2 cwt., and that if we increase the draught we must decrease the number of miles travelled, we have some clue to guide our comparison. The experiments show that, at the speed of $3\frac{1}{2}$ miles per hour, $1\frac{1}{2}$ acres can be done by each furrow in a day of ten hours, in a field of 250 yards long, and 2 acres in a field of 400 yards long, allowing for hindrances. Now, if we assume the use of an engine giving off not less than 24 nominal horse-power, of which about 4 horse-power is consumed in friction, the remaining 20 being given off in work in the plough equal to 20 cwt. draught—thus drawing 3 furrows or shares, 4-horse work each, 4 furrows 3-horse work—we shall then get over from $4\frac{1}{2}$ acres to 6 acres of the heavier work, and from 6 to 8 acres of the lighter work. If the land is lighter than either of these, less horse-power will be used, and in consequence of less hindrance, and the engine running always at top speed, an acre an hour can be easily accomplished.

843. The daily expenses are as follows:—

	S.	D.
Two men at 3s.,	6	0
Two men at 2s. 3d.,	4	6
One boy at 1s.,	1	0
Coals, from 10 to 14 cwt.,	14	0
Water, one horse and man,	6	0
Shifting, 24s. per week, or	4	0
	35	6

	$4\frac{1}{2}$ Acres.	6 Acres.	8 Acres.
Cost per acre, exclusive of wear and tear, respectively,	7s. 11d.	6s.	4s.
As against	16s.	12s.	9s. by horse labour.

844. A six-furrow plough might be made for light land, or a five-furrow driven faster, which would increase the quantity of work without increasing the cost materially; but reducing the cost forms but a small part of the advantages offered by steam cultivation. It is found that heavy land ploughed by steam is left in an almost perfect state of tilth, as it is not the plough but the weight of the horses trampling on the land that causes that solidity of the furrow-slice of which the advocates of rotatory cultivation complain.

845. This was exemplified in Wiltshire in 1857, where a piece of land ploughed by horses lay side by side with a piece of land ploughed by steam; the steam-ploughed was harrowed down and sown in perfect tilth after two days' dry weather, when the horse-ploughed more resembled a mass of boulders than a friable soil, and would require a fortnight's dry weather to render it workable. Any one who has watched the impression of his foot on the sand of the sea-shore, and has seen the distance to which the water is disturbed by his weight, as shown by the colour of the sand, will appreciate the effect of horse-weight on wet clay-soil.* The increased speed of the plough tends also to produce a quicker tilth.

* This is the turning-point in regard to the ploughing clay-soil. No doubt, horses' feet penetrate and consolidate when ploughing *wet* clay-soil; but there is as little doubt that horses' feet do not penetrate and consolidate *dry* clay-soil. The conclusion is, that clay, when wet, ought not to be ploughed with horses; but this naturally gives rise to the question, whether wet clay may be ploughed by steam? We answer in the negative, because *wet* clay-soil ought not to be ploughed at all, but left alone until it becomes dry by draining or evaporation.—EDITOR.

846. Section Second—*Grubbers.*—The grubber, or, as it is frequently, but erroneously, styled, the *cultivator*, is a comparatively modern implement, and seems to have sprung from the more ancient prototype, the brake-harrow, which it has now to a considerable extent superseded. It is in principle a member of the harrow tribe of implements; but while the harrow, or even the brake, acts superficially or to a very small depth in the soil, the grubber, from its greater weight, and from the form of its tines, penetrates the ground to any required depth. In respect to penetration, therefore, it approaches the plough, but its effects are simply to stir the soil, tearing up roots of plants at the same time, but produces no effect towards turning it up like the plough. It has been supposed that the grubber may be traced as far back as the days of Roman agriculture, but there is good reason for assuming that the instrument used by the Romans partook more of the brake than the grubber, and so far as has been traced in modern works, its application, in Scotland at least, goes no farther back than the year 1784, at which period an implement, then styled an *edgit*, of the grubber family, was in use by several agriculturists in the neighbourhood of North Berwick, East Lothian.*

847. From this period the grubber appears to have lain comparatively dormant till 1811, when the late Sir John Sinclair, Bart. of Ulbster, brought it in a tangible shape before the Dalkeith Farming Club. Sir John at that time described it as being known in England by the name of the *scarifier*. As might naturally be expected, therefore, it seems to have been an importation from England, but, like other implements and machinery already noticed, it came to a higher degree of perfection here than in its original soil, and it is only very recently that the newest forms of the grubber have appeared in England.

848. Many years after, Finlayson, Kirkwood, and others, cleared the way, and brought out those essential characters of the implement which have not yet been superseded except in minor details.

849. The original Scotch form of the grubber of 1784 appears to have been a wooden frame, in which, Mr Shirreff says, "the tines were fixed, standing perpendicular, the point not dipping, but forming a right angle with the tines. The wheels were only two; these stood in front of the machine, and being movable upwards and downwards, regulated the depth to which the tines were intended to work."†

850. The improved form of 1811 is figured in the *Transactions of the Highland and Agricultural Society* and other works of the period,‡ but still constructed in wooden framework; and having now four wheels, immediately supporting an external frame, to which was jointed another and internal frame carrying the chief part of the tines, it became better adapted to being raised out of the ground at pleasure.

851. The next great step in the improvement of the grubber was made by Mr John Finlayson, farmer at Kaims, in the parish of Muirkirk, Ayrshire, who, about the year 1820, brought out his *patent self-cleaning harrow* or grubber; but it does not appear that he actually procured a patent for the improvement. It was now made entirely of iron, and became a very effective implement, though cumbrous, and attended with some inconveniences arising from a deficiency in the means of raising the tines out of the ground.

852. Subsequent to the improvement by Mr Finlayson, Mr James Kirkwood, Tranent, East-Lothian, made some further improvements on the patent self-cleaning harrow of Finlayson, and ultimately, in 1830, brought out a grubber

* *Prize Essays of the Highland and Agricultural Society*, vol. xiii. p. 359-370.

† Ibid. ‡ Ibid.

differing materially from the former, and possessing properties that placed it superior to the other, the chief of which was the easy and perfect manner in which the whole of the tines could be raised from the ground.

853. Various other modifications were soon after brought out by different makers, among which we cannot omit mentioning that of the late Mr Wilkie, the well-known ploughmaker at Uddingston. Mr Wilkie's grubber is a very elegantly-constructed machine, possessing the self-cleaning principle in the tines; but, from its elaborate construction, its necessarily high price has probably been a bar to its more extensive introduction. Amongst these modifications, Finlayson's original grubber again underwent a marked improvement, in which, though the original shape has been preserved, a perfect mode of raising the tines from the ground has been engrafted upon it.

854. While these later improvements have been going on in Scotland upon this implement, corresponding exertions have been successfully made in England, where the improvements above alluded to have not only been followed, but are in some measure surpassed, under the names of Cultivators and Scarifiers. Amongst these, that of Richard Coleman is the most celebrated.

855. Such are a few leading points in the history of the grubber, and its progress to the present improved state. It is, and will continue to be, an important implement, whether for the working of summer fallow, the preparing of rough or foul land for green fallow, or for the purifying of land that has been suffered to become so foul as to be incapable of producing a crop in the ordinary mode of cultivation. Soils in the last-mentioned condition, by passing through a course of grubbing that may be done in a few days or weeks at most, may be brought into a crop-bearing state. The grubber, like many other novelties, was, on its reintroduction about 1811, held up as an implement capable of producing an entire revolution in the cultivation of the soil,* and was spoken of as something above human invention, superseding even the plough; it has now settled down into its proper sphere of usefulness, ranking at least next to the plough.

856. It will be unnecessary to attempt going into details of all the forms of the grubber, more especially of those early forms which are now entirely exploded; even the original of Finlayson's may be passed over as now obsolete, but which may be seen figured in the works of the day.† We shall therefore only describe some of those which have attained a character they are likely to retain; and of these, though it may not be in exact chronological order, Kirkwood's may be taken as the first in the order of description.

857. *Kirkwood's Grubber.* — In this machine the ingenious apparatus for elevating the tine-frame was, we believe, first brought out, and from it has been deduced all the various forms in which this effect is now produced, though, as we shall see, some of them are so much changed from the original as hardly to be recognisable; still the elements of the original are there, obtained in some cases at a greater, in others at a smaller, expense. The present form, as figured here, differs in some minor points from the original, but not so much as at all to alter the character of the implement, which is still essentially Kirkwood's, though the figure is taken from those manufactured by A. and G. H. Slight of Edinburgh. The chief points of difference are in the length of the axle of the hind-wheels; this, in the original, was so short as to bring the wheels close to the levers: now, the axle is extended so far as to place the wheels on the outside of the extreme tines. This extension of the axle

* See, for example, BEATSON'S *New System of Cultivation.*

† *Quarterly Journal of Agriculture*, vol. ii. p. 846.

gives the machine a broader base, and thereby a greater steadiness of motion; and to compensate for, and give support to, the extremities of the axle thus extended, it is supported by a trussed tie with king-posts.

858. Fig. 2, Plate XI., is a view in perspective of this grubber: it may be considered as consisting of two parts, the tine-frame, and the carriage with its wheels and handles, the two being connected by means of the apparatus for elevating the tine-frame, and by a joint-rod which is common to both, the whole being constructed of malleable iron, except the wheels. The tine-frame is of an irregular triangular figure, composed of two sides *a a a*; these are forged to the peculiar form represented in the figure, and to the following dimensions: from extreme *a* to *b′* in the oblique straight line, the distance is 25 inches, *b′* to *c′* 21 inches, and *c* to *a″* 39 inches; and the lengths on the opposite side correspond exactly with these; but the central distance from extreme *a* to *a″* is 6 feet 6 inches. The breadths, measuring from centre to centre of the tines, are at extreme *a* 4 feet 2 inches; *b′* to *b′* 2 feet 10 inches, and *c′* to *c′* 17 inches; the fore-part of the bars, forming the neck, approach to within $\frac{3}{4}$ inch of each other, between the points *d′* and *m*, and at *a″* they come in contact, and are fixed by the bolt at *a″*; the muzzle *a″ z* is simply a prolongation of the bars, and is provided with several holes in which the draught-shackle and hook can be attached to regulate in some degree the tendency to earth. That part of the frame *d′* to *m*, forming the neck, is raised 9 inches above the line of the body, measuring from the upper surface of the one to that of the other, and lies parallel with the body of the frame. The side-bars here described are $2\frac{1}{4}$ inches in depth and 1 inch in breadth, till they approach *d′*, when they are diminished in breadth to $\frac{3}{4}$ inch, and go on diminishing to $\frac{1}{2}$ inch at *a″*. The slot-holes for the tines are $2\frac{1}{4}$ inches by $\frac{3}{4}$ inch. Besides the connection at the point *a″*, the side-bars are connected by the joint-rod *g*, which ie $1\frac{1}{2}$ inches square at the middle, tapering and rounded towards the end, whers it terminates in a screw and nut of about 1 inch diameter; and a light stretcher *a′* is also inserted as a further support to the frame. The beam *b b* is $2\frac{1}{4}$ inches by 1 inch from *b* to *u*, and diminishes from *u* to *d′* to $\frac{3}{4}$ inch; it is kneed at extreme *b*, so as to leave space sufficient to receive the slot-hole for the middle tine, and it is bent upward at *u* to the height of 10 inches above the frame as before, for the purpose of receiving the bridle *u u′*; the end *b* of the beam is notched into the middle of the joint-rod *g* (which is here spread out to 2 inches in depth), and fixed by a screw-bolt, tapped into the end of the beam, while its fore-end is secured between the side-bars by a through bolt at *d′*. The tines, of which this form of the implement contains seven, *h h*, &c., are $1\frac{3}{4}$ inch by $\frac{3}{4}$ inch, bent at the point as in the figure, with a slight tendency to *earth*, and are flattened out at the point to a breadth of $1\frac{1}{4}$ to $1\frac{1}{2}$ inch; their length from the level of the point to the top is 20 inches, and they are secured at any required degree of earth by one iron wedge to each tine.

859. The *carriage* consists of the axle *d d*, on which are mounted the two handles or levers *c c c*, the axle passing through these, and fixed with cotterels on each side. At the distance of $13\frac{1}{2}$ inches from the centre of the axle, the levers are also perforated for the joint-rod *g*, the position of which in the tine-frame is such as just to allow the extremities to pass the axle when the frame is being raised or depressed. A third perforation is formed in the fore-end of the lever at *o*, 2 inches forward of the joint-rod, for the attachment of the stays. The levers extend backward to a length of $4\frac{1}{2}$ feet, and terminate in sockets into which wooden helves are inserted; and they are further supported by the stay-rod and bow *c′*. The carriage is now supported on the hind-wheels *f f*, of

22 inches diameter; and the fore-part of the frame on the castor-wheel *i*, of 13 inches diameter, with its sheers *k l*, and crank-lever *l m n*.

860. The connections between the carriage and frame, and which also form the elevating apparatus, are arranged in the following manner: The right and left stay-rods *o p q* and *r p s* are bolted to the levers at *q o* and *r s*, the perpendicular distance *g p* being 12 inches, and the like distance from the centre of the axle *d* to *p* 18½ inches, the two stays being brought together upon a stretcher-bolt at *p*, of 1 inch in length, having a screw and nut at each end. The connecting-rod *p t n* is 5 feet 2½ inches in length, ¾ inch diameter, and is jointed to the carriage by the short stretcher-bolt at *p*, and to the crank-lever of the front-wheel at *n*, which completes the arrangement by which the tine-frame is moved up and down in positions always parallel to the horizon.

861. Fig. 1 is a geometrical elevation of this grubber, showing in a more distinct manner the relation and the action of the elevating apparatus. In this the solid lines represent the machine as with the tines in the ground, the surface being represented by the line $x' x''$; and the repetition of the figure in *dotted lines* represents it as when the tines are elevated, and the machine in a travelling condition, the same letters applying in both positions, but in elevation with an *accent*. In the first position, applying the same letters as in the former figure, *a a* is the tine-frame, *b* the beam, *c* the handles or levers, *d* the axle of the carriage, *f* the hind-wheels, *g* the position of the joint-rod of the tine-frame, and *h h* are the tines. The front-wheel is shown in the sheers *k l*, and *l m n* is the crank-lever, *g p r* the stays, and *t* the connecting-rod.

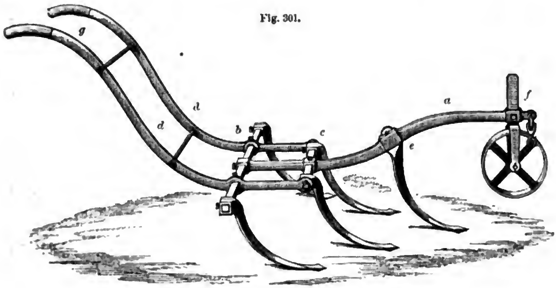
862. In the apparatus of the front-wheel, the distance from the sole of the wheel, where it touches the line $x' x''$, to the centre at *m*, is 23 inches, and from *m* to *n* 11¼ inches; and as the carriage-lever, though in a complicated form, is resolvable into a more simple one, which has the same proportions as the former, the point where the wheel touches the line $x' x''$ is the fulcrum, and a line drawn from the point x' to the joint at *p* will be parallel with, and equal to, $x'' m$, and *g p* will be equal to *m n*; and the point *p n* acting simultaneously by means of the connecting-rod *t*, rises by turning round the fulcrum x', while *m* rises through the same space by the point x'' turning round the point *m* in the opposite direction. By these motions the tine-frame will rise and fall through equal spaces before and behind, and thus preserve the parallelism of the frame in any position.

863. In working the machine it is requisite that the conductor have it in his power to regulate and preserve a uniform depth for the tines, and be able to withdraw the tines from the earth. To accomplish this part, the connecting-rod *t*, fig. 2, has small mortises punched in it, to the number of 6 or 8, at very close intervals between *u* and *p*, the rod being square at this place. A nut or slide-box y' is fitted to slide easily upon it; and having also a mortise punched through it corresponding to those in the rod, it can be fixed at any point by dropping a pin through this and any required mortise. The bridle $u\ u'$ consists of two similar parts bolted one on each side of the beam; and having the middle parts of its stay widened to admit the passage of the nut, it receives the folding-link *v* upon the bolt, on which the link turns freely. The handle *v x w* is made of such length as will bring the eye *w* within reach of the conductor; it is furnished with a cross-head *x*, and the end *v* being screwed into the link *v*, the handle can be shortened or lengthened at pleasure; and this is done to make the cross-head *x* fall in behind the end of the connecting-rod when the tines are in the ground, which thus lock them that they cannot rise out of the ground, although, from any malformation of the tines, they might have a ten-

dency to do so were this lock not applied; but while the tines preserve their due form, the lock is not required. A prolonged screw-nut at *p* is also put upon the handle; it is forked in the prolonged part; and when the tine-frame is raised out of the ground for travelling, the nut is adjusted to fall in before the checks of the stays at *p*, and thus keeps up the tine-frame without the continued aid of the conductor.

864. *Tennant's Grubber.*—In construction, this implement, as shown in fig. 301, is of the simplest form. The beam *a* has an eye formed at its hinder extremity,

Fig. 301.



TENNANT'S GRUBBER.

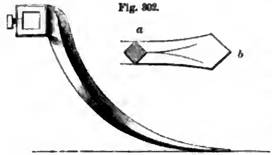
through which a square bar *b* is passed, and near it a similar eye carrying a second but shorter bar *c*. On the ends of this short bar are fixed the extremities of the stilts or handles *d d*, which also embrace the hinder bar *b*, by means of eyes similar to, but lighter, than those on the beam. Each of these cross-bars, *b* and *c*, carries two tines, formed with eyes to embrace the bar, and allow them to be shifted along it if necessary: pinching-screws are provided to secure them to the cross-bars in any desired position. The fifth and foremost tine is fixed in a mortise in the beam at *e*; and in another mortise, at the point of the beam at *f*, is inserted the stem of the wheel which regulates the depth to which the tines penetrate.

865. The dimensions of the different parts are as follow: The length of the beam, from the centre of the wheel at *f* to the front of the foremost tine at *e*, is 1 foot $10\frac{1}{2}$ inches; from *f* to the centre of the bar *c*, 3 feet 5 inches; and from centre to centre of the bars *b* and *c*, 1 foot 1 inch. The length from *f* to the end of the stilts at *g* is 7 feet 6 inches, beyond which the wooden handles project 8 inches. The beam immediately behind *f* is $1\frac{3}{4}$ inch deep and $1\frac{1}{8}$ inch thick; at *e* 2 inches or $2\frac{1}{4}$ inches deep and $1\frac{1}{2}$ inch thick; and from this it decreases to $1\frac{1}{2}$ inch square, or $1\frac{1}{2}$ by $1\frac{1}{4}$ inch at the back end. The square eyes are $2\frac{1}{2}$ inches each way, with holes just sufficient to allow the cross-bars of $1\frac{1}{2}$ inch square to pass through, and each furnished with a pinching-screw $\frac{5}{8}$ inch diameter. The iron of the stilts is $1\frac{1}{2}$ by $\frac{5}{8}$ inch, swelled out where they embrace the bars *b* and *c*, eyes $1\frac{1}{4}$ inch thick being formed for securing them to *b*, and give sufficient metal to carry a pinching-screw in each; but the eyes for securing them to the bar *c* are kept to the ordinary thickness of the stilt, $\frac{5}{8}$ inch. Behind the bar *b* the stilts are connected and stiffened by two stretchers $\frac{5}{8}$ inch in diameter. The hinder bar *b* is 3 feet 3 inches long, which allows its tines to be fixed at 36 inches between centres, and the front bar, 1 foot 10 inches long,

over all, with its ends reduced a little, to form shoulders for the eyes of the stilts to rest against, a small pin through the bar at each end keeping the stilt up to the shoulder: the width between the stilts at this point is 1 foot 8½ inches, to allow of the two middle tines being set to 18 inches between centres. When the grubber is standing level, the point of the beam to the underside is 1 foot 9 inches high, and the cross-bars 1 foot, and the height to the upper side of the handles 3 feet 6 inches.

866. With the exception of the first, all the *tines* are alike, and one is represented in fig. 302, to a scale of 1½ inch to a foot. The body is 1½ inch square, set diagonally, or with a corner in front, as shown in section at *a*. It is bent so as to form about a quarter circle in side-elevation, the upper end terminating in a cubical bead or eye 2½ inches square, pierced with a hole 1½ inch square, and furnished with a pinching-screw at the back. The point is steeled and drawn out thin to a breadth of 3 inches, and pointed as at *b*. The front tine is similar to the others, except in having a tenon at top, for fitting into the beam in place of the large eye.

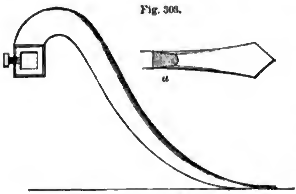
Fig. 302.



TINE OF TENNANT'S GRUBBER—SCALE, 1½ INCH TO THE FOOT.

867. Fig. 303 is a form of tine introduced by the late James Slight, and usually called the *swan-neck* tine. It has been found very useful where the land is foul, and where Tennant's form would be liable to choke at the top. The difference consists in making it rise about 3½ inches at the eye before bending downwards, so as to carry weeds over the top of the supporting bar when forced upwards on the tine. In section it is as represented at *a*, being in the central part 2 inches broad, 1¼ inch thick at the back, and ⅞ inch at the front, which is rounded: it deepens a little at the top, where it has an eye like the other, and is finished at bottom with an angular point also like Tennant's.

Fig. 303.



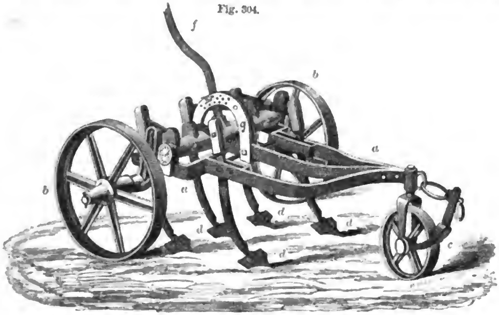
SWAN-NECK TINE OF TENNANT'S GRUBBER—SCALE, 1½ INCH TO THE FOOT.

868. The *wheel*, as registered by Mr Tennant, is an ingenious contrivance, intended to obviate the wearing-out of the eye from a want of oil. Instead of running on a simple pin, it runs on a tube furnished with ends or cups, which project inward, and partially cover the eye of the wheel. One or both of these ends must be loose, for getting the parts put together, and also for taking them separate for the purpose of oiling, which is done by filling a chamber formed in the eye for containing a supply of oil. The tubular pin and its ends are held in their places by a screw-bolt, which passes through all, and binds the tube to the sheers carrying the wheel. The ends of the eye are turned so as nearly to fit inside the cups.

869. *Coleman's Cultivator.*—This implement, manufactured by Mr Richard Coleman of Chelmsford, and which enjoys a high reputation in England, is represented in fig. 304, where *a a* is the frame, *b b* the two hind-wheels, *c* the front wheel. The tines *d d* are supported by the central bar *e e*, which is easily moved on its centres by the handle *f* (part only of which is shown in the drawing.) The handle *f* adjusts the depth to which the tines work, or lifts

them altogether out of contact with the ground: it moves in the slot of the semicircular guard *g*, and can be retained therein in any desired position by

Fig. 304.

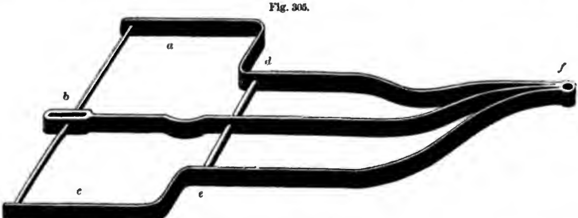


COLEMAN'S CULTIVATOR.

passing a pin through corresponding holes made in the guard *g*, and an aperture in the handle *f*. The adjustment of the tines *d d* is remarkably easy in this implement, and the whole mechanical details are well arranged, and adapted to the work to be done.

870. In fig. 305 is a view of the wrought-iron frame; the extreme length from

Fig. 305.

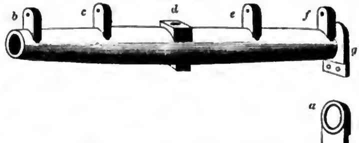


FRAME OF COLEMAN'S CULTIVATOR.

b to *f* is 6 feet, its width from *a* to *c* being 2 feet 10 inches. Five prongs are swung at the points *a b c d e* on bolts or studs ¾ inch in diameter. The front wheel *c*, fig. 304, is 16 inches in diameter, and the two hind-wheels *b b*, 2 feet 4 inches.

871. The barrel-spindle in fig. 306 is 2 feet 10 inches long, and works in sockets, one of which is shown at *a*, attached to the framing. The barrel-spindle is made hollow, which gives considerable strength with comparative lightness, and has snugs or projecting parts cast on its upper side, as *b c d e f*. The upper ends of the connecting-rods which move the prongs carrying the tines *d*, fig. 304, are inserted into the slots or mortise-holes of

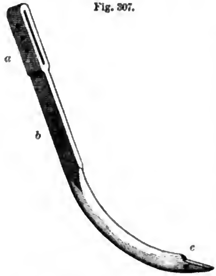
Fig. 306.



BARREL-SPINDLE OF COLEMAN'S CULTIVATOR.

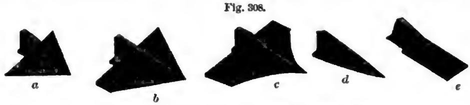
the snugs *b c d e*, fig. 306, and secured by pins passing through corresponding apertures. The lower ends of the connecting-rods are inserted in the mortise made in the upper part *a* of the tine, of which a view is given in fig. 307, and secured by pins passing through holes. The prongs are swung to the frame by bolts or pins passing through one of the holes at the part *b*. The length of the prongs is 2 feet 10 inches; they are made of wrought-iron, 2½ inches broad by 1 inch thick. They are curved as shown, and are notched at the extremity as at *c*, to fit into the mortise of the shares or tines, these being secured by pins passing through the holes shown in the figure. The shares, spuds, or points are made at intermediate widths between 1½ and 12 inches, for the various purposes for which this implement is applicable, whether for paring, breaking up hard land, working fallows, &c. Several forms are

Fig. 307.



PRONGS OF COLEMAN'S CULTIVATOR.

Fig. 308.



VARIOUS FORMS OF TINES FOR COLEMAN'S CULTIVATOR.

shown in fig. 308, at *a b c d e*. To regulate the height of the implement from the ground, the axle of the hind-wheels *b b*, fig. 304, is supported in the square hole of the boss *b* of the suspension-rack, fig. 309. This rack is connected with the frame, and held in its place by a swivel-bolt and collar *a*, which is made to fit the notches in the rack. The price of this implement is £6, 15s.

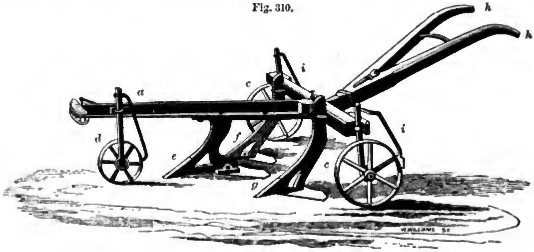
Fig. 309.

SUSPENSION-RACK FOR WHEELS OF COLEMAN'S CULTIVATOR.

872. The thickness of the turf removed with this spade depends much on the strength and skill of the workman, but it seldom exceeds 2 inches even in the softest parts of the ground, and more often 1½ inch on ordinary surfaces.

873. *Bentall's Broadshare.*—This implement, invented and manufactured by Mr E. R. Bentall of Heybridge, near Maldon, Essex, has a high reputation, and is most extensively used for the purpose of destroying weeds and loosening the soil after harvest. We give a perspective view

Fig. 310.



BENTALL'S BROADSHARE PLOUGH

of it in fig. 310, where *a* represents the beam of wrought angle-iron; to this is bolted the cross-arm *b*, which carries the two wheels *c c*; *d* is the small fore-wheel. The centre tine *e* is placed in advance of the two hind-tines *f g*: the stilts *h h* are secured by a bolt to an iron stay, secured to the cross-arm carrying the tines *f g*; *i i* are scrapers to keep the tire of the wheels clean of earth.

874. The following illustrations, drawn to a scale of ½ inch to the foot, represent various of the details of this implement. Fig. 311 is the centre tine; fig. 312 the side tine; fig. 313 is the centre-tine point—it penetrates the soil, and enables the share to enter the soil easily; fig. 314 the tine-point; fig. 315 is the broad-share, principally used for flat and stetch land.

Fig. 311.

CENTRE TINE OF BENTALL'S BROADSHARE.

Fig. 312.

SIDE-TINE.

Fig. 313.

CENTRE-TINE POINT.

Fig. 314.

TINE-POINT.

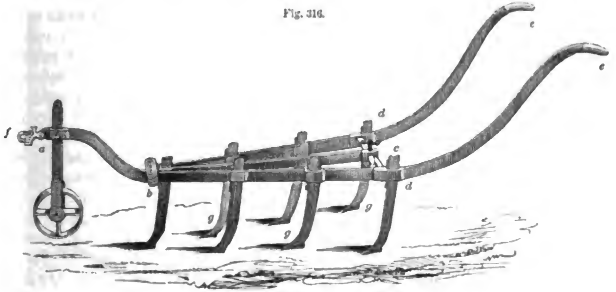
Fig. 315.

BROAD-SHARE.

875. Stirring the soil with grubbers, cultivators, or broad-shares, should not be regarded as an equivalent to ploughing it; but grubbing is an excellent process when surface weeds are desired to be destroyed, and the dry warm pulverised soil to be retained at the surface in spring, instead of the raw cloddy earth which would in that season be brought up by the plough.

876. *Drill-Grubber.*—The common *drill-grubber*, fig. 316, is a light and convenient implement drawn by one horse. It consists of a central beam *a b c*, the neck part of which, *a b*, is 18 inches long, the body part, *b c*, 3 feet 6 inches; and of

Fig. 316.



THE COMMON DRILL-GRUBBER.

the two wings *b d*, which are extended to *e e*, forming the handles, the length from *d* to *e* is 3 feet 4 inches; the extreme length from *a* to *e* thus being 8 feet 4 inches. The neck part of the beam is 1½ inch square, and peened or rounded, and this strength is carried past the first tine; the remainder of this bar, as well as of the wings, is 1¼ inch deep by ½ inch thick, the handles becoming lighter backward. The beam is punched at the front for the passage of the stem *a* of the wheel, and also at *b* for the fixing of the two joint plates for the wings, as well as for the front tine; and it is also perforated horizontally at the end *c* for the quadrants of the wings. The wing-bars require to be very neatly forged in forming the swells, in which the tine-holes are to be punched, and also for the joint at *b*, where they are hinged to the beam, between the two joint-plates, which, being riveted dead upon the beam, leave a chamber on each side for the reception of the ends of the wing-bars, and through these their joint-bolts are passed. The wing-bars are each furnished with a quadrant-bar riveted into the wings at *d d*; the tail of the quadrants passing through the mortise at *c* are secured by a pinching-screw fixing the wings at any required width. To the point of the beam is affixed a simple bridle *f* with a cross-web and shackle, giving a small range of yoke right and left; the rise of this point is 10 inches above the line of the body of the beam. The front-wheel, whose office is to regulate the depth of the grubbing, is usually 8 or 9 inches diameter, set in the sheers of the stem, which may be 20 inches long, and is 1½ inch broad by ½ inch thick. The tines *g* are 15 inches long, the body being 1½ inch broad by ½ inch thick, forged with duck-feet not exceeding 2½ inches broad, and pointing slightly forward.

877. In many localities this implement is used for all the purposes of horse-hoeing among turnips and potatoes, but it is not suited for paring or earthing-up; and having cheapness as well as utility as a recommendation, it is very generally approved of. It is, however, subject to variety in the different districts where it is employed; in some it is shortened to five tines, in others lengthened out to nine, and in many cases the tines are plain-pointed, or not exceeding 1 inch broad. It is frequently also made with the tines standing in *zigzag* position; but except in the second pair of tines, this is of little importance, as those behind the second are sufficiently far apart to prevent them getting choked with weeds.

878. SECTION THIRD.—*Harrows.—Land-rollers.—Clod-crushers.—Press-wheels. The Harrow.* — Considering the operation the harrow has to perform, in covering the seeds that have been cast upon the surface of the soil, it is an implement of no small importance; and yet its effects are apparently rude and uncertain, while its construction is of the simplest order. So simple, indeed, is this construction, that at a very remote period it appears to have taken that form which, in so far as the simple principles of its action are concerned, is almost incapable of further improvement. Variations in size, in weight, in materials, and slight changes of form, have from time to time been proposed and effected; but yet no important change has been made in the action of the implement, though amongst these changes a more uniform distribution of its effects over the surface of the soil has been attained. The only important improvement on the harrow of which we have any historical data, was achieved about fifty years ago by, we believe, the late Mr Low, Gordonbank, Berwickshire, father of Professor Low, who, till lately, honourably occupied the chair of Agriculture in the University of Edinburgh; and this improvement lay chiefly in the *form*, though it also afforded a more uniform distribution of effect.

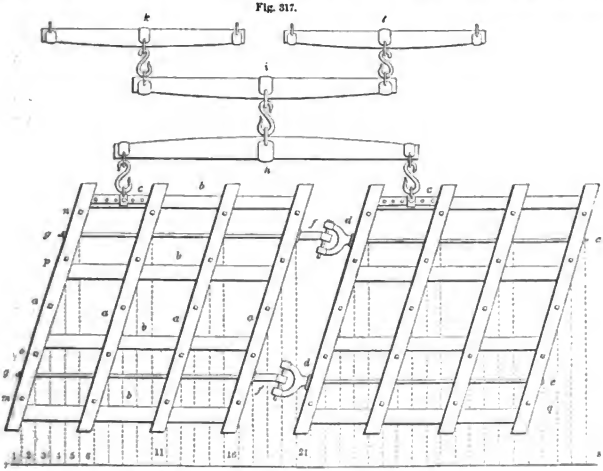
879. *Rectangular Harrows.*—Previous to the period just alluded to, the seed-harrow was always constructed in the form of a rectangular frame of wood, consisting, as it still does, of four longitudinal bars, known, in the language of the agricultural mechanic, by the term ***bulls***, which are framed together by mortising, with four lighter transverse bars, or ***slots***. The dimensions of the rectangular harrows are, on an average, 3 feet 9 inches in breadth, measuring over the bulls, and 3 feet 10 inches in length over the slots. The bulls are generally about 4 feet 6 inches of extreme length, 3 inches in breadth, and 3 to 3½ inches in depth; the slots are 3 inches in breadth, and ⅞ to 1 inch in

depth. Each bull is armed with 5 tines or teeth of malleable iron, about 10 inches in length. They are fixed in the bull by being driven into an auger-hole bored through it, and project downward from 6 to 7 inches.

880. Rectangular harrows are yoked three in number together, at the second bull and fore slot, to a long master swing-tree. Being loose, they are much agitated; and although their action is correct enough, they do little execution on rough and cloddy ground; and yet it is on the strong soils they are chiefly used. They are apt to ride on one another, especially at the turnings, though this defect has been partially remedied by the use of a bar, named a *rider*. Three horses are usually yoked abreast to them, and the middle horse seems much oppressed in warm close weather.

881. *Rhomboidal Wooden Harrows.* — The *improved form* given to the harrow, as alluded to in par. 878, changes the rectangle into a rhomboid, and this, when duly proportioned, gives to the implement, as has been supposed, as high a degree of perfection, in point of form, as it appears capable of attaining. Fig. 317 represents a pair of the rhomboidal harrows

Fig. 317.



RHOMBOIDAL WOODEN HARROWS, WITH THEIR YOKE OF SWING-TREES

in the working position. The frame of these harrows consists of the same number of parts as the common sort, already alluded to. Four bulls *a a a a*, and four slots *b b b b*, the breadth of the frame over the bulls, at right angles to them, is 3 feet 6 inches; and in the same manner, over the slots the length is the same, but the bulls extend at each end 4 inches beyond the slots, making their entire length, including the obliquity, about 4 feet 6 inches. The dimensions of the parts vary a little, according to the quality of the material employed, from 2½ to 3 inches in breadth by 3 to 3½ inches in depth, for the bull. The slots are from 2½ to 3 inches in breadth, and from ¾ to 1 inch in depth, the bulls being mortised, and, when the slots have been inserted, are fixed with wooden pegs driven through the bulls. In each harrow an iron bar *c c*, having a number of holes punched in it, is likewise fixed into mortises in the two outer bulls on the left side, for the attachment of the yoke. Each bull is divided into four equal parts, the extreme division being about 1 inch clear of the mortise of the slot, and at each division the bulls are bored with an auger for the reception of the tines, and in thus boring, a slight inclination forward below is given to the tines, though this, it must be admitted, is not of very great importance. The length of the tine is about 10 inches, of which 6 or 7 inches project below the bulls; and it has been recommended that the front row should be 7 inches, the succeeding rows diminishing gradually to 6 inches, to compensate for the effect of draught of the horses tending to elevate the fore-parts of the harrows. This tendency to rise in front is not so great as has been supposed, for the weight of the swing-trees and whole yoke will nearly compensate for the effect of the angle of draught. In all cases of this kind, the yoke consisting of chains, hooks, and swing-trees—of which the latter, in the harrows-yoke, form a portion of considerable weight—the system resolves itself into a catenarian curve, more or less perfect, of which the point *c*, where the yoke is attached to the harrow, will approximate to the apex of the curve, and consequently to a horizontal line, thereby neutralising the tendency to rise in the front of the harrows.

882. There is one point in the improvement of this harrow that appears to us of even more importance than the rhomboidal shape; it is the joints or hinges ***d d***. In the one harrow, fig. 317, the tail of the double joints of the hinge is prolonged into a bolt *d e*, *d e*, passing through all the bulls, and secured with screw-nuts *e e*. In the other the single joints are in like manner prolonged into the bolts *f g*, *f g*, thus serving to add greatly to the strength as well as to the efficiency of the harrows. The loose joints *d f*, *d f* have been found to answer their purposes much better than the well-fitted joints originally given to them, by their allowing of a great freedom of action, and the double joints *d d* are therefore now usually made as in the figure, the span of the bow *d* being about 6 inches, with a small eye at each end to fit the joint-bolt. The eye of the single joint *f* is about 1½ inch or 2 inches diameter, having thus great freedom to play upon the joint-bolt.

883. From the figure of the rhomboidal harrow, when duly constructed, it can only perform its maximum of effect when drawn forward with its slots at right angles to the direction of its motion, and this is effected by the master swing-tree *h*. This tree, for harrows of the dimensions here described, requires to be 4 feet 8 inches in length between the points of attachment, and it is connected to the harrows by means of the S hooks and shackles at *c c*. The balance of draught of the harrows is adjusted by shifting the shackles into the different holes of the bars *c c*, until the harrows are found to lie at right angles to the draught when in motion; and this, be it observed, is not attained by having an equal number of tines on each side of the centre of the swing-tree *h*, for there is found to be a greater resistance to the forward motion of the implement on the left than there is upon the right side, arising, it is supposed, from the tines presenting a broader surface to resistance on that side than on the other. The other parts of the yoke, *i*, *k*, *l*, are the common plough swing-trees, fig. 288.

884. The objects to be attained on the *construction* of the rhomboidal harrow are chiefly uniformity and equal distribution of effect from the tines, and to cover the greatest breadth of surface, with such effects. In these respects it has been supposed that the rhomboidal affords advantages over the rectangular form, but such advantages seem to fall only within certain limits; for the rectangular harrow, if due attention is paid to its construction and position

of yoking, and *if mounted with the hinge-joints*, will perform all the functions ascribed to the rhomboidal harrow with equal effect. Though the rectangular form presents no advantage in point of expense, there would be this advantage in construction, that, by keeping simply to one dimension of breadth, no mistake could occur with the maker to mar the attainment of the objects in view; whereas we find rhomboidal harrows made at all angles of obliquity, though the length and breadth may be the same in all; and such being the case, many of them must be defective in some, if not in all the points sought for. To exhibit this more clearly, and to render the basis of construction of this simple implement practically intelligible, let us suppose that a pair of harrows carrying *forty tines* are to be so constructed as to cover 9 feet in breadth, we shall have 39 spaces between the extreme tines, which are to form equal intervals. Draw a base-line *r s*, fig. 317, and having set off from a scale, or at full size, a distance *r s* equal to 9 feet, divide this into 39 equal parts, and from the points of division draw the dotted lines at right angles to *r s*, the distance between the divisions will be 2.76 inches, or say $2\frac{3}{4}$ inches, which represents the distance at which the tines will pass through the ground. Having determined, also, the distance between the tines as they stand in the bulls to be $9\frac{1}{2}$ inches, set off, on the first dotted line 1, any distance *r m*, which last point *m* will be the place of the first tine. With a length of 38 inches, or 4 tine spaces as before fixed, set off from the point *m* a distance *m n*, cutting the fifth dotted line in *n*, which last point will be the place of the fifth tine, or the foremost in the first bull. If a line is then drawn through the points *m n*, it will cut the divisions 2, 3, 4 in the points *o a p*, indicating the three intermediate tines of the first bull, and the line *m n* is the true position of the central line of the bull, forming an angle of 73° nearly with the base-line. A line drawn through *m* to *q*, and parallel to *r s*, will determine the position of the first tine on each succeeding bull, where the line intersects the 6th, 11th, 16th, 21st, &c., of the dotted lines of division; and lines drawn through those last points of intersection parallel to the first line *m n*, will determine the central line of all the bulls in the pair of harrows. It is then only necessary to extend the length of the bull requisite to contain the mortise for the slot, with a sufficient extent beyond to prevent the bursting of the wood: this, as already stated, may be about 4 inches, or the bulls will be about $4\frac{1}{2}$ feet in length.

885. Were it desired to have the tines so placed as to follow in the ground at equal distances of $2\frac{1}{2}$ inches instead of $2\frac{3}{4}$ inches, in this case the distance between the extreme tines would be 39 times $2\frac{1}{2}$ inches, or 8 feet $1\frac{1}{2}$ inch. The line *r s*, fig. 317, would now be made 8 feet $1\frac{1}{2}$ inch, and being divided into 39 equal parts, and the lines of division drawn as before, a repetition of the process described (par. 884) will give the true form of the rhomb for this particular breadth, and so of any others; and it should be particularly observed, that in any case where the rhomb has been correctly laid down, the harrows should progress with the front row of tines at right angles to the line of direction in which they are drawn forward. Attention to this will insure the best possible effects from the harrow, and at the same time cover the greatest breadth of surface that it is capable of harrowing, to the best advantage.

886. *Rule for Constructing Rectangular Harrows.*—We have said that the common rectangular harrow is capable of producing equal effects with those of the rhomboidal; and though this cannot be said of all common harrows, the construction of such as will do this is not more difficult, while it is, perhaps, a little less expensive. The chief difference lies in the mode of applying this harrow, for, when duly constructed, it is only necessary, in

order to produce equal intervals of the tines, to yoke the harrows in such position as will make the bulls lie upon the ridge with the same degree of obliquity that those of the rhomboidal shape occupy when they are drawn in the position due to the angle of their respective rhomb. It is necessary, however, in order to secure the due performance of the rectangular harrow, to pay attention to its construction as regards the distance between the bulls, and the rule is simply this: Whatever breadth the pair of harrows are intended to cover, divide the whole breadth into a number of divisions, one less than the whole number of *tines* in the pair, and the distance from centre to centre of the bulls must be made equal to as many of these divisions as there are tines in each bull. Thus, taking the first case of the rhomboidal harrow (par. 884) we have 5 times 2¾ inches nearly, or 13¾ inches for the distance between the centres of the bulls, or 3 feet 8 inches in breadth over all. To complete the arrangement, the harrows must be *jointed* as in the rhomboidal form, and mounted with iron draught-bars, as at *c c*, fig. 317, so that the point of draught can be adjusted to bring the harrows to their proper position; and here it may be remarked that they should never be drawn by the extreme angle; but if not hinge-jointed, the angle with the second bull, and the fore-slot, will be tolerably near to the true point of draught. A common and a very useful practice has long existed of coupling two harrows together by a bar of wood or iron, called a rider. This bar falls loosely at each end upon a stud projecting upward from the second bull of each harrow, and the bar being adjusted to that length which keeps the two harrows at their proper distance, serves to prevent them from riding over one another, and to make them cover their full extent of surface. The introduction of the rider was an evident approach to the more perfect modern improvement of the hinge-joints.

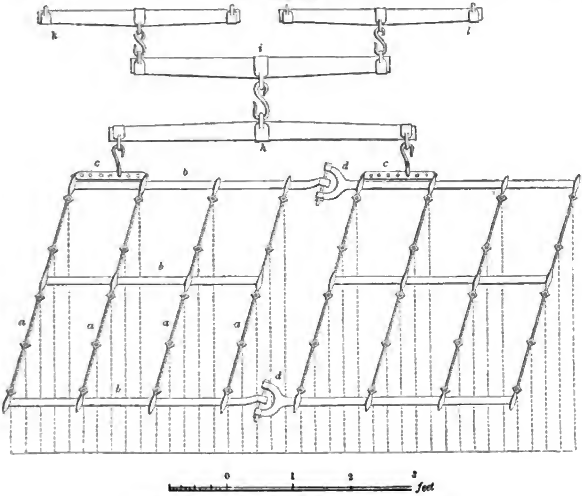
887. *Rhomboidal Iron Harrows.*—The extensive application of iron has of late years brought the use of that material to the formation of the harrow as well as of the plough, and iron harrows are now coming very generally into use, both in the rectangular and the rhomboidal form. Fig. 318 represents the malleable-iron rhomboidal harrow, as commonly constructed, and its dimensions are the same as already given for those of wood. The arrangement of the parts is somewhat different, and, from the nature of the materials, the dimensions of the parts differ also more materially. Thus, the bulls *a a a a* are ½ inch in breadth and 1 inch in depth, swelled out where the mortises for the slots are formed, and also for the tines, their ends projecting only 2 inches beyond the slot. The slots *b b b* are 2 inches in breadth, ⅜ inch in depth, and there being only three of them, the middle one is so placed as to be free of the middle row of tines; while the end slots are elongated towards the meeting sides of the pair, and are there formed into the hinge-joints *d d*, as formerly described for the wooden harrows. The draught-bars *c c* are inserted in the projecting ends of the first and second bulls, and retained in round pivot-holes; the swing-trees *h i k l* are the same as described for the wooden harrows.

888. The construction of the iron harrow is so similar to the others that it is unnecessary to enter into further details regarding it; but it may be remarked, that, from the almost imperishable nature of the materials, as compared with wood, there seems every reason to expect the iron implement will entirely supersede the wooden; and though the price of the iron harrows is considerably above that of wood, the additional first cost is more than repaid by the greater durability of the iron. There is good reason also to believe that, by a construction more adapted than the present to the nature of the material, the price may yet be considerably reduced.

889. The *form of the tines* of the harrow, as regards their effects in stirring

the soil and covering the seed, is deserving of inquiry. In the wooden implement, we are, from the nature of the material, confined to one form of tine; that

Fig. 318.



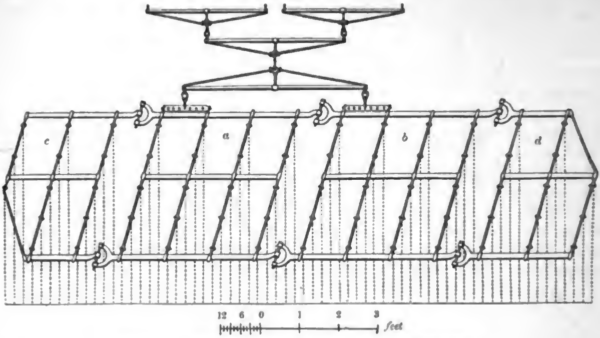
IRON RHOMBOIDAL HARROWS, WITH THEIR YOKE OF SWING-TREES.

which has for its horizontal section an oblong square, the tines in these cases being $\frac{7}{8}$ inch broad by $\frac{5}{8}$ inch thick, must, for the safety of the wood, have the greatest dimension lying in the direction of the fibres of the wood. Another and a better form, for the purpose of stirring the soil, is that which has its cross section forming an exact square of $\frac{3}{4}$ inch on each side, and inserted in the bull with its diagonal pointing in the direction of the progressive motion. This form and position of the tine, however well adapted to the soil, cannot, with propriety or safety to the implement, be used in the wooden harrow, from the powerful tendency it has to split the wood. In the iron implement this difficulty does not exist; and as this form of tine is in every respect best adapted to the intended purpose, it should never be omitted in the iron harrow. Whatever be the cross section of the tine, in that part which passes through the bull, the projecting part is tapered towards the point, not uniformly but a little barrelled, and terminates in an obtuse point. In all wooden harrows the tines are simply driven firmly into the wood after it has been bored. In most iron harrows they are fixed in the same manner; but as the tines are sometimes liable to become loose, when simply inserted and driven down by the hammer, they are, when a more perfect construction is followed, fixed by being driven from below, and secured by a screw-nut above.

890. *Grass-seed Harrows*, or those that are employed for giving a light covering to grass-seeds when sown, differ from the common harrow in no respect except in dimensions and weight. They have generally the same number of tines, bulls, and slots. The breadth over all is about 3 feet, or from that down

to 33 inches, and the distance between the tines about 7 inches, giving a length of bull 3½ feet; and the tines vary from 5 to 6 inches in length. Fig. 319

Fig. 319.



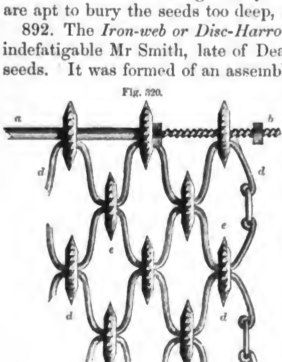
GRASS-SEED IRON RHOMBOIDAL HARROWS, WITH WINGS AND SWING-TREES

shows, at *a b* in the centre parts, harrows exactly in form to the iron harrows, fig. 318; but grass-seed harrows ought always to have wings attached to them, as are *c* and *d*, in order to cover a ridge at once, as grass seeds only require one turn of the harrow to cover them sufficiently with soil. The extreme angles of the wings are cut off to allow the harrows to turn more quickly and easily. Grass-seed harrows may be made of wood or iron. The swing-trees may be of wood, fig. 288, or of trussed iron, as shown in the figure.

891. Grass-seed harrows are not so generally used by farmers as they should be, the common ones being usually employed to cover in the grass seeds; but these are apt to bury the seeds too deep, to the injury of the succeeding grass crop.

892. The *Iron-web or Disc-Harrow* is a late invention by the ingenious and indefatigable Mr Smith, late of Deanston, for the purpose of covering-in grass seeds. It was formed of an assemblage of annular discs of cast-iron, of the size and shape of the common playing-quoit, and these were interweaved with iron-wire of about ¼-inch diameter in a certain regular form, until the whole formed a flexible web, in which the discs had liberty to play and roll about within small limits. The web was 6 feet in length by 3 in breadth, and was simply dragged over the ground, when it gave the surface a finish superior to anything hitherto attempted, on the correct principle that grass-seeds should be as lightly covered as possible.

Fig. 320.



IRON DISC OR WEB-HARROW.

893. In fig. 320 is a form of disc-harrow as manufactured by Messrs Richmond and Chandler, Salford. The discs *e e* in this form are of cast-iron 3 inches diameter, about ½ an inch thick in the centre, and gradually tapering off to a thin-edged periphery, which is serrated or notched, as shown in the cut. The connecting-

links *d d d d* are of malleable rod-iron about $\frac{3}{8}$ths of an inch diameter; the length of the links is 3 inches; the breadth $1\frac{1}{2}$ inch. This makes the distance between the discs 6 inches from centre to centre, the lateral or side distance being 3 inches. The side-rods *a b* are 1 inch diameter, and are connected together by means of screws, as shown at *b*.

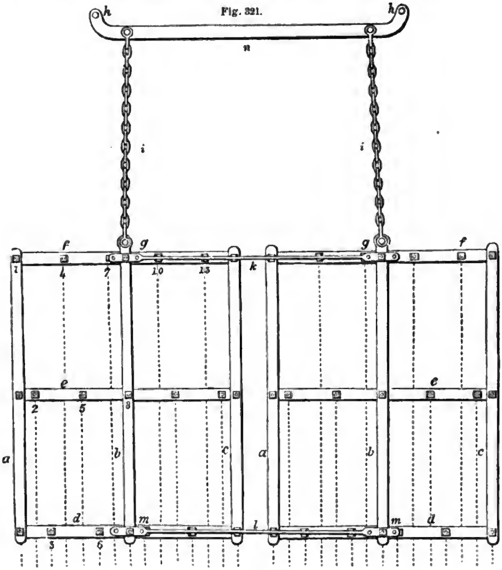
894. *The Brake-Harrow* is only an enlargement of the common implement, wherein every part is increased in size and weight for the purpose of breaking down and pulverising rough and stubborn land. Brakes are made of various forms, such as rectangular, rhomboidal, and triangular; and every form has its advocates, the preference being given frequently to that which accident had thrown in the way of the experimenter; and without taking measures to compare its effects with those of other forms, the implement is marked as the most perfect of its kind. There appears no good reason for concluding that any one of the above forms is better than another, provided proper weight is put in the implement, and the tines of proper length and number, and disposed in a manner that, with a duly-applied draught, will make an equal distribution of its pulverising effects over the surface which it covers. The extended application of draining, and the increasing employment of the grubber, appear to be superseding the brake-harrow.

895. *The Drill-Harrow* is another implement of recent introduction; like the other members of its tribe, it is of extremely simple construction, and from its having been first applied to potato-culture, it is frequently styled the *potato-harrow*. This harrow is always worked in pairs; and to render it applicable to its intended purpose, it is made of an arch form, partially embracing the curvature of the ridglet or drill. The two leaves of the pair are connected by two coupling-rods, which are formed to expand or contract to any required width of drills; and each leaf is furnished with a chain, to which a draught-bar or swing-tree is attached, and to which again the horse is yoked; the bar and chains, in this mode of yoking, serve by their weight to produce such a catenarian curvature as to make the vertical line of traction leave the harrows nearly in a horizontal line, giving them thus the full effect on the drill. Simple though the construction of this implement be, we frequently see a malformation in the placement of its tines; its breadth does not exceed 26 inches, and therefore the number of its tines need not exceed 18, though a streak at every $1\frac{3}{4}$ inch should be required: notwithstanding this, we frequently see these harrows with as many as 24 tines, and with such a number, unless a very careful division is made in their placement, many of them will follow in the track of others, and are hence of no use. In laying out this simple harrow, if the rule laid down in (884) applicable to all harrows is attended to, such useless waste of labour and materials might be saved, and the work for which the implement is intended will be equally well done.

896. Fig. 321 is a geometrical plan of a pair of the rectangular drill-harrows, in which a regular division of the tines is observed; and as the harrows are 26 inches from centre to centre of the outside bars or bulls, and the number of tines 15, they will draw streaks on the surface at equal distances of $1\frac{7}{8}$ inch nearly: the three bulls *a b c*, and the three cross-bars *d e f*, form the body of the harrow; the breadth over all is 27 inches, and the length 33 inches; the bulls and bars are all $1\frac{1}{4}$ by $\frac{3}{8}$ inch. There is no slotting, as in the common harrow, but the bulls and bars are simply crossed, and secured by a small bolt and nut; or they may be riveted together, except where a tine falls in the crossing, when it is secured by the nut of the tine itself. The bulls and cross-bars are simply punched for the tines, which are each secured by a screw-nut. The

middle bull of each harrow is prolonged a little forward at *g*, and punched for the shackle of the draught-chain *i i*, which is affixed thereto by a bolt. The tines

Fig. 321.

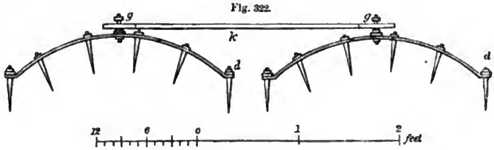


THE POTATO-HARROWS.

are about 4 inches in length below the bars, and are $\frac{5}{8}$ inch square at the shoulder, tapering to a blunt point. The streaks of the tines may be easily traced by following the order of the numerals 1, 2, 3, 4, 5, 6, 7, 8 in the left-hand division of the left-hand harrow, and they will be found to be at regular distances.

897. Fig. 322 is a cross-section, at the front bar, of both the leaves of the harrow, showing the arched form and direction of the tines. The rise of the arch

Fig. 322.



CROSS-SECTION OF THE POTATO-HARROWS.

is 5 inches, but this may be varied; and if the arching is flat, the tines towards the apex should be shorter than those towards the sides of the harrow, to prevent injury to the young potato-plants. In the front bar the right-hand tine *d* may be left out, as its place may be taken up by that of the third bar, leaving 5 tines. In the second cross-bar there are also 5 tines, and 5 in the third. The two leaves are connected and kept at due distance by the coupling-rods *k l*, fig. 321, and *k*, fig. 322, which are ⅝-inch diameter, and flattened at the ends to the extent of 5 inches, and have three perforations made at each end, at 1½-inch pitch, or closer if thought necessary; this construction of the coupling-rods affords the means of adapting the harrows to any width of drills. The fastening of the coupling-rods is shown at *g g*, fig. 322. The draught-chains *i i*, fig. 321, are about 2 feet long, and are shackled to the draught-bar *n*, to which the horse is yoked by the eyes at *h h*. The pair of harrows are drawn by one horse, walking between the drills; the weight of the pair, with the mounting, is about 90 lb., and the price from 30s. to 35s. complete.

898. *Triangular Drill-Harrows* are considered by some agriculturists as superior in effect to the rectangular form: with due attention to the division and placement of the tines, they may no doubt be rendered equally effective, and probably more so, but the advantages are not prominently marked.

899. As in the forming of a drill or ridglet for green crops, one side has more earth upon it than the other, the germ of the seed enclosed within the drill, on making its way to the day between the joinings of the two furrows of which the drill is composed, must necessarily appear at one side of the drill: the top of the drill is usually levelled with the common harrows, but, as these are flat, the top of the drill becomes too much levelled down. Both the rectangular and triangular drill-harrow, having the form of the drill, are implements better suited for the purpose than the common harrows. In turnip culture the sowing-machine itself levels the drills, but in potato and bean culture the drill-harrow is the best implement for levelling the drills.

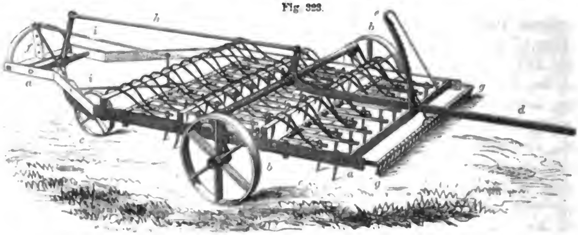
900. *Howard's Zigzag or Diagonal Harrow.*—This form of harrow has a high reputation in England, and is extensively used. It is made entirely of iron. Each portion of a harrow is composed of eight rhomboidal frames affording twenty tines, which are fixed at the angles of each rhomboid by means of stops or guards which keep the nuts from shaking loose. Four of the rhomboidal frames are placed together, end to end—the two in the middle in line, and one at each end at a reverse angle with the middle one—the whole four forming a figure not unlike the letter Z, or zigzag form. Each harrow is composed of two portions of four rhomboids or zigzags placed parallel to one another, at a distance equal to the breadth of a rhomboid, and are coupled together at both ends by rods jointed in the centre. Three of these harrows supporting 60 tines are coupled together, and connected to a long master whipple-tree by six bolts, two to each harrow, with hooks and staples. The whole presents a series of zigzag frames, six in number, and equidistant from each other; their entire breadth occupying 9½ feet or 10 feet, according to the size of harrow. A 9½-feet harrow costs £3, 14s.; a 10 feet, £4, 4s.

901. *Coleman's Expanding Harrow.*—The object of this implement is to combine in one the advantages of a wide and a narrow, or a coarse with a fine harrow. This is effected by having the tine-beams jointed in the principle of the parallel ruler. There are five longitudinal beams placed in the direction in which the harrow works; each pair are connected by four diagonal bars, the ends of the two adjoining sets meeting at an angle. The ends of all the diagonal bars are jointed to the main beams. The whole is connected to the whipple-tree by five chains; and by allowing the points of attachment by which the longitudinal beams are brought nearer to, or placed further from each other, the relative distances of the trees from each other are retained in all the

adjustments. To cover a space 9 feet wide, the price of this form of harrow is £4; for heavy work, £4, 15s. To cover 12 feet wide, light work, £5; heavy work, £5, 15s.

902. *Ross's Moss-Extirpating Harrow.*—In fig. 323 we give a perspective view of an implement for extirpating moss out of old pasture, invented by Mr Alex-

Fig 323.



ROSS'S MOSS-EXTIRPATING HARROW.

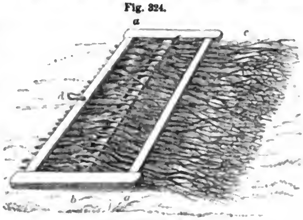
ander Ross, late land-steward at Corehouse in Lanarkshire. It consists of a malleable-iron frame *a a*, 5 feet 6 inches in length, and 4 feet 6 inches in breadth, mounted on two wheels *b b*, 1 foot 9 inches in diameter. The fore-part of the frame *a a* is produced forward and slopes inwards until its two sides approach as near as to admit a bar of iron, which connects the end of the frame *a*, and a parallel axle which turns on gudgeons in the framing, and which supports a castor-wheel *c*, the shank of which is prolonged upwards into a crank, and which wheel supports the front part of the frame *a a*. The entire frame *a a* is capable of being raised and lowered by a system of leverage similar to that used in the common grubber, as in fig. 2, Plate XI.; this is effected by the lever *d*, through the means of the rod *h*, connecting the cranks of the lever *d* and the castor-wheel *c*; and which lever is retained in any position desired by the notches in the side of the curved guide *e*. A semicircular guard is secured in front to support a vertical bar *f* provided with three holes for attaching the draught-shackle; the diagonal stays *i i* strengthen the semicircular guard by connecting it with the frame *a a*. The body of the frame *a a* is filled up with three rows of tines, each containing 15 tines—or 45 in all, and 3½ inches apart—each tine having an independent motion from a bar having an attachment at each end to the frame *a a*. The tines are 7 inches long, 5 inches below the frame, and ½ an inch above it, and are driven through an eye in the outer extremity of each of the bars, which are alternately short and long. Above each row of tines, at the height of 3 inches above the frame, is a bar of iron, to which are attached springs which press individually upon the extremities of the tine-bars. Under the tine-bars are placed rods, stretching across from side to side of the frame *a a*, to prevent the tines falling down when the implement is turning round in the field or conveyed along a road; and these rods are so adjusted as to admit of being shifted backward and forward to keep the tines up at any given height; and the nearer these rods are to the outer extremities of the tine-bars, the less fall will the tines have. A rake *g g* is suspended behind by joint-bolts to the ends of the frame *a a*, so that it can be lifted up at pleasure by a bow-handle and hooked on to a small iron rod suspended from the curved guide *e*. Cleaning-rods are placed between each alternate tooth of the rake, the office of which is to collect the moss as it is passed from the tines. Care should be taken to depress the lever *d* to the lowest notch of the guide *e* before turning the machine, in order to elevate the tines at the highest point above the ground.

903. This machine requires three horses yoked abreast, with equalising draught-bars such as fig. 291 to work it easily. It goes over $7\frac{1}{2}$ acres in 10 hours. The best time for using it is in spring, before the grass begins to grow. Once going over the pasture will generally suffice for the extirpation of the moss, but should it be abundant, a second going over, at right angles to the first, will accomplish the end. In one instance, at its first use, at Corehouse, the machine scratched up forty-nine cart-loads of moss over $10\frac{1}{2}$ acres of grass on the lawn.

904. This machine will be found a valuable implement for scratching the surface of any pasture before top-dressing is applied to it, and then the bush-harrow sends the top-dressing to the roots of the grass, after which a roller is passed over the top-dressing. Where much moss has been scratched off, a little grass-seed should be sown over the surface and rolled in, whether top-dressing has been applied or not.

905. *The Bush-Harrow.*—Fig. 324 represents a bush-harrow which is useful for scratching-in top-dressing on pasture-land. It consists simply of a frame of wood, *a a*, having two strong end-bars 3 feet long, and three connecting-bars 7 feet long; the middle one, *b*, being also strong like the end-bars. The three bars are interwoven with the smaller branches or croppings of trees *c*, which scratch the ground as the harrow is drawn forward by a horse attached by a swing-tree to the hook *d*.

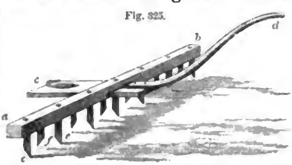
Fig. 324.



THE BUSH-HARROW

906. *Snow-Harrow.*—In par. 748 we gave an illustration of the snow-plough; as a companion implement, we here give the snow-harrow in fig. 325. It consists of a single bull, *a b*, $4\frac{1}{2}$ inches square, 6 feet long, and in the middle of which, on the under-side, a piece of $1\frac{1}{4}$ inch plank, *c*, 3 feet long, is sunk flush transversely for the attachment of the draught-hook *c* and the stilt *d*, to steady the motion of the implement. In the bull *a b* are fixed, by screw-nuts, at intervals of 10 inches, 7 cutters, *e e*, &c., 9 inches long and $1\frac{3}{8}$ inch broad, sabre-pointed, with the points turned backwards, so as to be less liable to be arrested by obstacles on the surface of the ground. Between these cutters are fixed 6 shorter ones, *f*, &c., 3 inches long, having their points turned forwards. This implement, dragged by one horse, ridden by a boy, and the stilt held by a man, cuts the frozen snow into strips of 5 or 6 inches in breadth, and exposes it to the air.

Fig. 325.



THE MOUNTAIN SNOW-HARROW

907. While the snow-plough, fig. 287, is used for disturbing deep snow in spring on hill pasture, the snow-harrow is best suited when the snow is thin and hardened on the surface.

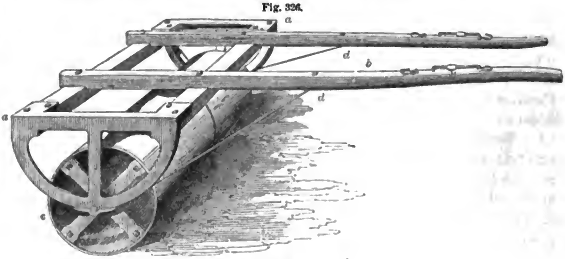
908. *The Land-Roller.*—The common land-roller is an implement of great simplicity of construction, the acting part of it being a cylinder of wood, of stone, or of cast-iron, and in many cases its only appendage is a rectangular frame of wood, consisting of two strong end-bars, selected for having a curva-

ture to keep clear of the ground. In these the gudgeons of the roller are borne, and which are connected by two transverse rails, to one of which the horses are yoked.

909. Simple as this implement appears, there is hardly an article of the establishment in which the farmer is more liable to fall into error in his selection. From the nature of its action, and its intended effects on the soil, there are two elements that should be particularly kept in view—*weight* and *diameter* of the cylinder. By the weight alone can the desired effects be produced in the highest degree, but these will be always modified by the diameter. Thus, a cylinder of any given weight will produce a greater pulverising effect if its diameter is one foot, than the same weight would produce if the diameter were 2 feet; but then the one of lesser diameter will be much worse to draw; hence it becomes necessary to choose a mean of these opposing principles. In doing this, the material of the cylinder comes to be considered. In the first place, *wood*, which is frequently employed for the formation of land-rollers, may be considered as least adapted of all materials for the purpose; its deficiency of weight and liability to decay renders it the most objectionable of all others. Second, *stone*, though not deficient in weight, possesses one marked disadvantage, liability to fracture, which of itself is sufficient to place stone rollers in a doubtful position as to fitness. This brings us to *cast-iron*, which is undoubtedly the most appropriate of all materials for this purpose. It is unnecessary here to enter into the inquiry as to the most advantageous diameter for a land-roller; the subject has already been elaborately discussed:* let it suffice to say, that experience has proved that a diameter of 2 feet is, in any circumstances, the one that will produce the best effects with a minimum of labour from the animals of draught; the weight being of course proportioned to the force usually applied, which is in general two horses. The weight of roller, including the frame corresponding to this, is from 12 cwt. to 15 cwt.; but it is better that the roller itself be rather under the weight, and that the carriage be fitted up with a box, in which a loading of stones can be stowed, to bring the machine up to any desired weight.

910. In a large and heavy roller, in one entire cylinder, the inconvenience of turning at the headlands is very considerable, and has given rise to the improvement of having the cylinder in two lengths; this, with a properly-constructed carriage, produces the land-roller in its most perfect form.

Fig. 326.



THE LAND-ROLLER.

911. Fig. 326 is a perspective of the land-roller constructed on the foregoing principles: *a a* is the carriage-frame, consisting of two semicircular ends

* *Quarterly Journal of Agriculture*, vol. i. p. 700.

of cast-iron, connected by two transverse bars of hardwood, and these last are crossed by the horse-shafts *b*. The cylinder *c* is in two lengths of 3 feet to 3 feet 3 inches each, and 2 feet in diameter; the thickness of the metal is from ¾ of an inch to 1 inch, according to the weight required; and each half-length of the cylinder has a cross fitted into each end, through the centres of which the axle passes. The axle, in consequence of the cylinder being in two lengths, requires to be of considerable strength, usually 2¼ inches diameter, and of malleable iron; upon this the two sections of the cylinder revolve freely, and the extremities of the axle are supported in bushes formed in the lower part of the semicircular end-frames. Two iron stay-rods *d d* pass from the end-frames to the shafts as an additional support to the latter.

912. The price of the land-roller, fitted up as here represented and described, is, according to weight, from £10 to £14.

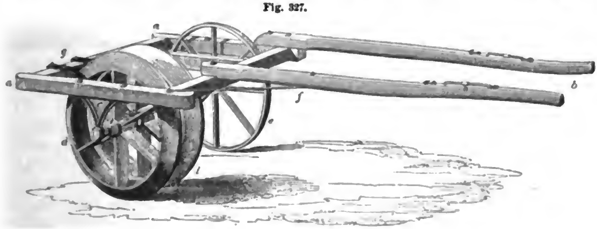
913. The smooth land-roller is more suited to compress light soil, and to make even the surface of new grass in spring, than to crush down large hard clods on clay land.

914. *Ransome and Sims' Barley-Roller.* — The barley-roller manufactured by Messrs Ransome and Sims, Ipswich, consists of two separate 10-inch cylinder rollers 5 feet long, of cast-iron, mounted on a wooden framing: when rolling the land, one cylinder is a little in advance of the other, but in a parallel line, the two inner ends crossing one inch, or two, so as to leave no part of the land unrolled; the rollers, being joined by a hook and eye loosely, adapt themselves to an uneven surface. Price £10, 10s.

915. *The Presser-Roller.*—This is an implement of comparatively recent introduction to the operations of the farm, and, like many others of the useful class of agricultural machines, its origin is to be traced to England. Although the presser does not take its place in the first rank, yet it possesses qualities whose effects on the soil give it a position by no means low in the scale of usefulness. The chief object of its application is to produce consolidation in the soil over a narrow space, in which space the seeds of plants are to have root; hence its effects are applicable only to the drill system of culture, and that only under particular circumstances, namely, consolidating soils whose texture is too loose and friable for the continued support of wheat plants, and to produce close contact in the furrow-slices of lea when ploughed for a seed-furrow. With the use of this implement wheat has been grown in some parts of Scotland successfully after lea.

916. The *Presser-roller* is represented in its most common form by fig. 327,

Fig. 327.



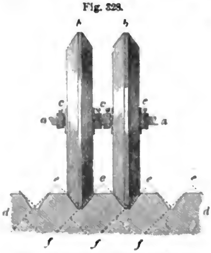
THE PRESSER-ROLLER.

which is a view of the machine in perspective, and is of extremely simple construction. The carriage consists of a rectangular frame *a a*, its length over the front and back bars is 3 feet 8 inches, and its breadth over the sides 4 feet

8 inches; a third longitudinal bar is introduced between those of the back and front solely to increase the rigidity of the carriage-frame. A pair of horse-shafts *b* are bolted upon the frame, the nigh-side shaft being laid upon the side-rail, and the other at the usual distance, to afford space for a horse to travel. A cast-iron bracket is appended by bolting to each side-rail: one of these is seen at *c*; its eye or centre descends to a distance of 8 inches below the bottom of the rail; an axle of 2 inches square extends between, and is supported in the eye of the bracket in which it turns upon its journals; this axle carries the two pressing-wheels *d d*, which are fitted to turn with the axle, but are movable in the transverse direction, and provided with the means of being fixed at any desired distance apart, though 9 to 10 inches is the usual space. The axle carries also the light carriage-wheel *e* of 2 feet 10 inches diameter, which may be placed either outside or inside of the carriage-frame, and is usually made of cast-iron, turning upon the axle, this being requisite for the more convenient turning round of the machine. The off-side shaft *b*, having but an imperfect connection to the carriage-frame, is supported by the iron stay-rod *f*; and two iron-scrapers *g* are attached to the hind-bar for the purpose of throwing off any soil that may adhere to the wheels *d d*.

917. Fig. 328 is an edge-view of the two pressing-wheels detached from the carriage, in which *a a* is the axle broken off, *b b* are the two pressing-wheels as they appear edge-ways; they are 2 feet 10 inches of extreme diameter, and their breadth 5½ inches, their weight being about 2 cwt. each; the rim or periphery of the wheel is sloped off on both sides to an angle of about 70°, forming two opposite conical frustræ, but a cylindrical band is left in the middle, of about 1½ inch in breadth. The pressing-wheels are held at the required distance by the square collars *c c c* fitting round the axle and sliding upon it to the proposed distance apart, where they are fixed by the pinching-screws *c c c*: *d d* represents a transverse section of ground undergoing the pressing process; the shaded part of the section exhibits the state of a soft loose soil when pressed by the roller, and the dotted lines *e f*, *e f*, that of newly-ploughed lea undergoing the operation of consolidation.

Fig. 328.



EDGE-VIEW OF THE PRESSING-WHEELS.

918. With reference again to fig. 327, the pressing-wheels *d d* are to be understood as running always upon the last turned-up furrows but one; while the carriage-wheel *e* runs always upon the solid land, where the horse also walks, the shafts being placed at that side. The most convenient method of using the presser-roller is for it to follow two ploughs, and to operate as every two furrow-slices are laid over.

919. But the presser is now being more advantageously used as to *time*, in the consolidation of soft soils, by being constructed with *four*, *six*, or more pressing-wheels; and in this form the carriage-wheel is not required. In using the presser of this construction, the field must be ploughed for the seed-furrow all over, either entirely or in part, before the pressing is begun; and the field is regularly gone over by the presser, which, from its now increased weight, will require two horses. In this form, with six pressing-wheels, and with the two horses, the machine will press-roll from 8 to 9 acres in a day.

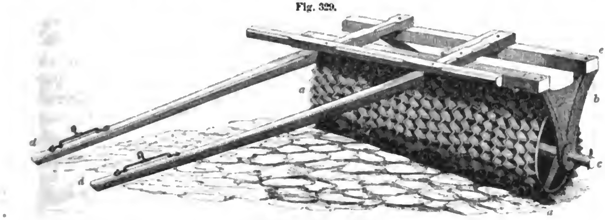
920. There remains to be observed, in regard to the larger number of wheels, that, in order to secure facility of turning about, the wheels must either be

all set upon a round axle, or they must be set upon an axle in two lengths, if it is continued in a square form; and there is consequently required a middle bearing for the meeting ends of the axle. For this purpose a third bracket is suspended to the middle rail of the frame, *a a*, fig. 327.

921. The price of the two-wheeled presser is £6, 10s.; and for each additional wheel, with its mounting, £1, 12s.

922. *Crosskill's Clod-Crusher.*—This is one of the most efficient implements of its class, and is represented in perspective in fig. 329, where *a a* is the roller,

Fig. 329.

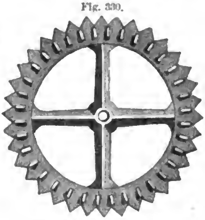


CROSSKILL'S CLOD-CRUSHER.

6 feet in length and 30 inches in diameter; *b* a cast-iron end-frame at each end of the roller, bolted to the wooden frame *e*, to which are bolted the horse-shafts *d d*. The frame-ends *b* are placed upon the axle *c*, the ends of which are prolonged to form arms on which wheels are placed, and kept on by means of coterels, for the removal of the roller from one field to another. When the wheels are to be placed or removed, a hole is dug in the ground under each wheel, while the roller rests on the ground.

923. The roller consists of a number of toothed wheels, supported on four-feathered arms, and an eye formed in the centre fitted to move easily on the axle *c* of the roller. Fig. 330 shows a side-view of one of those wheels, by which its action upon the soil may be easily understood. When such a great number of angles, acting like so many wedges, are brought into contact with the indurated clods, they infallibly split them into numerous fragments, and the repetition of the process produces a well-pulverised surface. The effect is quite different from that of the plain roller, fig. 326, with which, if a clod does not crumble down at once with its pressure, it is forced into the soil in a solid state.

Fig. 330.



SIDE-VIEW OF ONE WHEEL OF THE CLOD-CRUSHER.

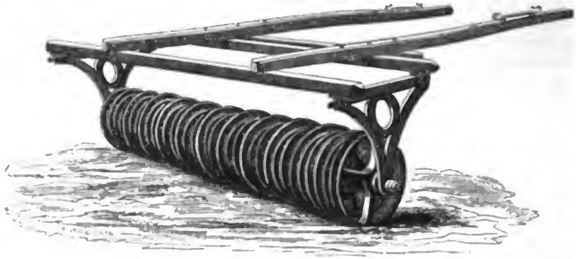
924. The price of this roller, 5 feet 6 inches long, and 30 inches diameter, is £18 with, and £16 without, travelling-wheels.

925. This roller is a very efficient implement for compressing the surface of light soil after it has been sown with barley and grass-seeds, and the effects are equivalent to the action of the grass-seed harrows, fig. 319, and the smooth roller, fig. 326, both of which implements may be dispensed with when this roller is employed for this particular purpose.

926. *Cambridge's Patent Press-wheel Roller.*—In fig. 331 this implement is used as a self-cleansing clod-crusher, and also for rolling meadow or pasture land infested with the wire-worm or grub. The length of the implement varies from 5 feet to 8 feet, and the diameter from 15 to 26 inches.

The number of discs or wheels in one form of this roller is 25; of these 12 are large, and 13 of small diameter. The small ones begin and end the

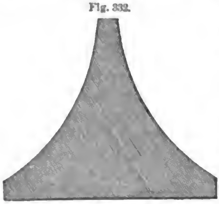
Fig. 331.



CAMBRIDGE'S PRESS-WHEEL ROLLER.

series. The interior diameter of the small discs is 1 foot $5\frac{3}{4}$ inches, the exterior diameter 1 foot $8\frac{1}{2}$ inches. The interior diameter of the large discs is 1 foot 7 inches, the exterior diameter 1 foot $9\frac{1}{2}$ inches. The face of the disc is 3 inches broad. The periphery of the disc is not parallel-faced like the tire of a wheel, but is provided with a central rib or projection a quarter of an inch in breadth, a curve being hollowed out on each side of this, extending to the sides of the disc. The breadth of the projection is thus made to increase gradually from a $\frac{1}{4}$ of an inch to 3 inches, the breadth of the face of the press-wheel. Fig. 332 is a section of the rim of the press-wheel. The press-wheels are placed eccentrically on the main axle, so that one is always in advance of the other; they are thus continually crossing each other in their revolutions; a grinding action on the clods on which they operate being produced, and a self-cleansing action insured. The price, from £10 to £20.

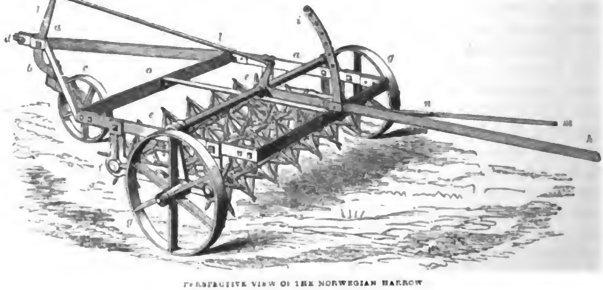
Fig. 332.



SECTION OF THE RIM OF THE PRESS-WHEEL.

927. *Norwegian Harrow.*—This implement, manufactured by Mr James Kirkwood of Tranent, is formed entirely of iron, and consists of a frame carrying

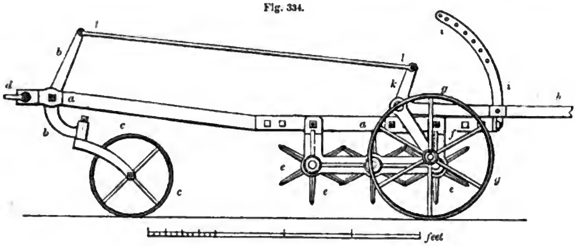
Fig. 333.



PERSPECTIVE VIEW OF THE NORWEGIAN HARROW three axles fitted with star-shaped wheels, and mounted on three supporting wheels with a lever-purchase and connections acting on all simultaneously for raising or lowering the body as in some of the grubbers. Fig. 333 is a perspective view, fig. 334 a side-elevation of the implement. The letters refer to both figures.

928. The frame consists of two side-bars *a a*, fig. 334, 2¼ inches deep and ⅝ inch thick, parallel for a distance of 3 feet 6 inches from the back end, thence

Fig. 334.



A LONGITUDINAL SECTION OF THE NORWEGIAN HARROW.

sloping inwards until they nearly meet at the front, where they embrace, and form a support for the jointed crank-arm *b b*, which carries the front castor-wheel *c c*. In front of this they come into close contact, and are held together by a bolt, which also serves to support a shackle *d* for attaching the horses. Two cross-bars connect the parallel portion of the frame, the hind one 2¼ inches by ⅝ths, and the front one 2¼ inches by ½ inch, with the ends kneed inwards about 5½ inches, and fixed to the sides by two screwed bolts in each knee. These cross-bars are connected by a bar *o*, 1½ inch by ⅝ inch along the centre of the machine, kneed and fixed by bolts at each end. The frame thus formed is 4 feet 6 inches wide over the sides, and 3 feet 6 inches in length over the cross-bars. From the foremost of these to the bolt on which the lever of the front wheel is jointed is 3 feet, and from that to the extreme point 6 inches; thus making the total length of the frame 7 feet. The axles of the star-wheels *e e e* are supported in a cast-iron frame *f* at each side, formed of a kneed bar 3 inches by ¾ inches, feathered on the outside, with bosses for the axles to run in, and bolted to the side-bars of the main frame, the centres of the three axles being 6 inches below the frame. The distance from the back end of the frame to the hind axle is 10 inches, and the axles are 11 inches apart between centres; they are each 1¼ inch square, turned at the ends for running in the cast-iron supports; the fore and hind ones each carry 13 star-wheels, and the middle one 12—thus allowing the teeth of the middle star-wheels partially to interlace with and revolve between the spaces of the other two sets. Each star-wheel is 13½ inches diameter over the point; the teeth, 6 in number, about 1 inch square at the bottom, and tapered to a blunt point; the eye is 4 inches deep and 2½ inches diameter at the ends, and cast with a hole full 1¼ inch square, to slip easily on to the axle. Half the number of the star-wheels are put on the axle with the points standing in the same direction, and the other half, occupying the alternate spaces, are placed a quarter of a revolution from this position. This arrangement breaks the line of the teeth of the star-wheels, and allows each set to revolve coincidently like a roller when the teeth catch the ground. The two hind carriage-wheels *g g* are 1 foot 10 inches in diameter and 2¾ inches broad, and are supported by cranks 10½ inches long, attached to a shaft 1¾ inch diameter, supported by a small bracket at each end bolted to the frame; the centre of the shaft being 1¾ inch above the frame, and 1 foot 4½ inches from the hind cross-bar. On the middle of the shaft is fixed a lever *h*, 6 feet 6 inches long, 2 inches by 1 inch at the neck, and tapered to 1¼ inch by ½ inch at the extreme end. At the point where it passes the hind bar of the frame it is swelled and mortised to embrace a curved arm *i i* about 1 foot 10 inches long, 1½ inch broad, and ½ inch thick, and which is secured to the hind bar by two bolts. A number of holes are made in the arm at various points, and a hole of corresponding size in both sides of the mortise of the lever *h*. By lifting the lever *h* to any point in the height of the curved arm *i i* till the apertures coincide, and passing a pin through them, the lever *h* is supported at any desired point. This pin is attached to the end of a light lever *n m*, fig. 333, which is carried nearly the whole length of the side of the main lever *h*, to which it is jointed, and has a spring provided to it which keeps the end *m* pressed, and retains the pin in the apertures of the mortise of the lever *h* and of the curved arm *i i*. To withdraw the pin, the end *m* of the lever is pressed out; this disconnects the lever *h* and the curved arm *i i*, and allows the lever *h* to be moved up or down as desired. Where the end of the lever *h* joins the axle of the hind-wheels *g g*, it is kneed or bent upwards, and furnished at the upper extremity with an eye, the centre of which is 7 inches from the centre of the axle. To this eye the forked end of a connecting-rod *l l*, 4 feet 11 inches long, and ¾ inch diameter, is jointed by a bolt; the other extremity of the rod *l l* being similarly jointed to the end of the crank-lever *b b* 12½ inches long, the centre of which works in a bolt in the end of the frame at *a*, and is continued downwards to support the front castor-wheel by a double-swivelling arm, the diameter of which is 15 inches, the breadth of bore being 2¼ inches: the distance of joint-bolt of lever *b b*, from centre of wheel *c c*, is 1 foot 8½ inches.

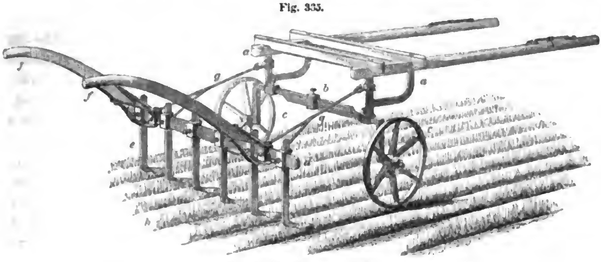
929. This implement is very efficient in its effects. Its action is to reduce large clods into very small ones by the insertion of the points of the star rays *e* into them, to split them into pieces by their reiterated action. The larger clods are split into pieces by the first row of rays; the second row splits these into smaller ones, and the third row splits these again into still smaller pieces.

930. SECTION FOURTH.—*Horse-Hoes.*—Wheat sown in rows is weeded with the hand-hoe, and also with horse-hoes. Where the extent of drilled crops is considerable, hand-hoers are unable to clear the ground of weeds before the crops advance to a state in which it is improper to go amongst them. Hence the need of assistance from the more expeditious horse-hoe.

931. *Smith's Steerage Horse-Hoe.*—There are many forms of horse-hoes for cleaning the ground between the rows of corn. A very ingenious and simple form is the steerage horse-hoe contrived by Mr William Smith, Northampton. It is shown in perspective in fig. 335, where *a a* is the framing, which also constitutes the horse-shafts, supported on iron brackets, which in their turn are supported on an iron axle *b*, as high as to permit the crop hoed to pass under it. The axle, bent down at both ends, works in the wheels *c c*. These form the carriage portion of the machine. The hoe consists of a bar *d*, which bears the shanks *e*, of six triangular duck-footed hoes or shares, made to embrace as many rows of corn, at the ordinary breadth of 7 inches asunder. The handles *f f*, by which the driver guides the hoes along the centres of the rows, are attached to the bar *d*. The

carriage and hoe are connected by means of the rods *g g*, which, at one end, are attached to the handles *f f*, and at the other linked on by eyes to hooks in the hind part of the brackets, which support the framing or shafts *a a*. The rods *g g* are

Fig. 335.

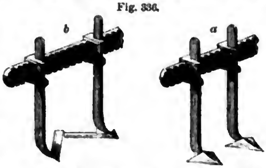


SMITH'S STEERAGE HORSE-HOE.

strengthened by curved rods passing under the bar *d*, and welded at both ends to the under part of *g g*. When the rows are placed wider than 7 inches, the axle of the frame *a a* is expanded to the requisite width by being slipped outwards through the collar, and fixed at any given width by the pinching-screw at *b*.

932. Fig. 336 represents two different sorts of shares used in this hoe, one, *a*, being the ordinary one for narrow rows of 7 inches; the other, *b*, to answer the broadest width of 18 inches. The share *b* consists of a long rectangular feather attached to each shank placed in a diagonal direction across, and meeting in the centre of the drill. The inclination of their edges allows the shares to clear themselves of the soil while they are cutting the weeds under the surface.

Fig. 336.



LONG AND SHORT SHARES FOR SMITH'S HORSE-HOE.

Having the bar *d*, fig. 335, as long as the width to which the axle *b* may be expanded, the requisite shares might then be affixed to it, required to hoe the number of rows determined on—and thus the hoes may be increased in number from 6 to 12, and the breadth hoed from 3½ to 7 feet; but from 4 to 5 feet in width is the best one for doing the work quickest and most effectually. To obtain that distance, 8 hoes at 7 inches wide give 4 feet 8 inches; 6 hoes at 9 inches wide give 4 feet 6 inches; and 6 hoes set at three doubles as *b*, at 18 inches wide, give 4 feet 6 inches.

933. The prices of this horse-hoe, at these respective widths, are—with 6 hoes, £4; 8 hoes, £4, 10s.; and 12 hoes, £5, 10s.

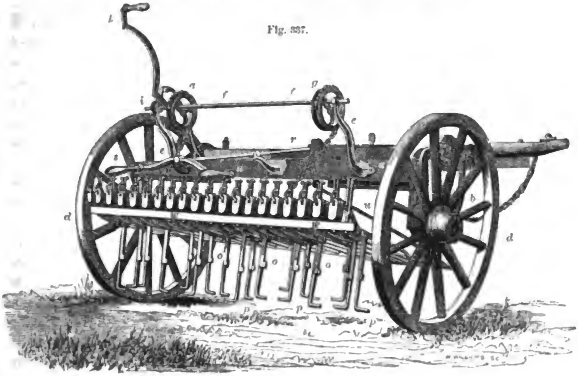
934. In using this hoe, the horse is put into the shafts *a*, fig. 335. The driver holds on by the handles *f f*, and steers the hoes along the centre of the rows *h*, which he is enabled to do by the movement of the rods *g g* upon the hooks attached to the brackets at *a a*. Should the horse swerve from the row he walks in, the driver directs the hoes in their proper rows, until the horse regains his former track. A steady horse will not leave the row he is placed in, from one end of the landing to the other, and only a steady one should be employed in such work as horse-hoeing. A steady man, to steer the hoes, is as requisite as a steady horse, otherwise carelessness will send the hoes through the rows of corn-plants, and cut them through as well as the weeds.

935. *Garrett's Horse-Hoe.*—In Plate XII. we give two views of this implement, of which fig. 1 is an end and fig. 2 a back elevation. The following is a description of the various parts, and the mode of operation. Similar letters are shown on the similar parts in both figures; *a a*, fig. 2, is the wood sill, 7 feet 2 inches long, 4 inches deep, which carries the different working parts of the machine; *b b* the cast-iron brackets bolted on to the sill, to support the axles *c c* of the travelling wheels *d d*, 4 feet in diameter. To the main sill *a a* brackets *e e* are bolted, on the upper end of which are bearings, in which the horizontal shaft *f f* works. On this shaft are keyed eccentric wheels, *g g*, 10 inches in diameter, with V or grooved peripheries. A lever *h*, 2 feet 4 inches long, is fixed to the shaft *f f*, by which the eccentrics *g g* can be moved through any desired portion of their revolutions. They can be maintained in any position by the pawl of the ratchet-wheel *i*, fig. 2, attached to the bracket *e*, going into the teeth of the ratchet-wheel *i* fixed on the end of the shaft *f*; *j j* are projecting parts at each end of the main sill *a a*, supporting arms or brackets *k k*, to which are jointed at the lower extremities swing-irons or levers *l l*. These swing-levers *l l* are jointed at their lower extremities to the ends of a horizontal bar, to which the levers *m m m*, fig. 1, are jointed as at *n*; these levers carrying the wrought-iron coulter-bars or stalks *o o*, to which the blades or hoes *p p* are connected. To the centre of the sill *a a* an iron bearing *q* is bolted on, to carry the spindle *r* placed at right angles to the sill *a a*; at the extremity of this a cross-handle *s s* is fixed. The spindle *r* is extended forwards, and provided at its extremity with a suspending lever or arm *t*; to the end of which a lever *u u* is jointed, the other extremity of which is jointed to the left-hand swing-lever *l*. The coulter-stalks *o o* are kept in position by four spring guards *x x x x*, two at each end of the mortise-bar *w w*. To keep the two outside levers out of work when required, springs attached to these guards are used. The hoe-guards on the outside are shown with weights *y y*, these being used on very hard soil. The remaining guards *z z z* are without springs; part of these guards are shown in the drawing with weights attached; 1, 1 are boxes in which to keep an extra supply of hoes; 2, fig. 1, a wrought-iron stay for supporting the guards; 3, 3, chains attached at one end to the bar *w w*, and at the other end to the wheels *g g*.

936. In working the implement, the blades or hoes must be adjusted to the breadth between the rows, allowing a little on each side to spare. The coulter-bar *w w* must then be lowered, and with it the stalks *o o*, so that the blades *p p* shall penetrate the soil to the depth required. This lowering of the coulters is effected by depressing the handle *h* slightly, so as to ease the pawl of the ratchet-wheel *i*; this being released, the shaft *f* is allowed partially to revolve, and with it the grooved eccentric-wheels *g g*; this slackens the chain 3, 3, and the bar *w w*, and the coulters and weights *y y* are allowed to fall. On the adjustment of the hoes in the soil being effected, the implement is drawn carefully across the field, so as to keep the hoes as nearly as possible in the direct lines of the drills. Any deviation from this is compensated for, by the attendant who, following behind, by means of the cross-handles *s s*, gives a lateral movement to the bar *w w*, and the coulter-stalks *o o* and blades *p p*. According as the one end of the cross-handle *s s* is raised or depressed, the end of the suspension-lever *t*, fig. 2, is moved to the right or left—describing a curve, as shown by the dotted arrow curve—acting on the lever *u u*. This lever being jointed to the swing-levers *l l* connected with the coulter-bar *w w*, a lateral movement from right to left, or *vice versâ*, is imparted to it, and, through its agency, to all the coulter-stalks *o o* and blades *p p*.

937. Fig. 337 gives a perspective view of this machine, bearing the same letters of reference. The price of it varies from £19 to £21.

Fig. 337.



PERSPECTIVE VIEW OF GARRETT'S HORSE HOE.

938. Just recently the Messrs Garrett have invented certain improvements in the construction of the horse-hoe described above, which consists in an improved mode of suspending the mortise-bar, to which the hoe-levers are connected, with the view of facilitating the raising and lowering of the bar for the purpose of adjusting the hoes to the proper angle of working, according to the nature of the ground for which the machine is to be used.

939. In the *Illustrated Inventor* of the 13th February 1858 is given a perspective drawing and longitudinal section of the modified horse-hoe, accompanied with a description of its construction, which we extract as follows: "At the opposite sides of the ordinary framing of the implement is mounted one of a pair of screw-shafts, so as to be capable of being turned on their bearings without receiving an endway motion; they are each provided with a right and left-hand screw-thread, to which are fitted travelling-nuts, tapped to work on the screw-threads, and move (as the shafts are turned) towards or from each other, according to the direction of the rotation of the screw-shafts. Jointed to and pendent from these nuts are rods or levers which are jointed in pairs at their lower ends to the extremities of the mortise-bar, and serve to support that bar in a horizontal or other desired position. The rotation of the screw-shafts is effected by means of winch-handles applied to their squared heads, which project beyond and in rear of the framing. Mounted loosely upon a plain portion of each of the screw-shafts, and at about the middle of their length, is a swinging-guide, intended to receive one of a pair of guide-bars or rods, which are jointed to the opposite ends of the mortise-bar. These swinging-guides and guide-bars are employed to steady the mortise-bar in its upward and downward movements; but it should be stated that they are not absolutely necessary for the efficient action of the implement. The hoe-levers are connected as usual to the mortise-bar, and are supported and raised in the ordinary manner at their hinder ends.

940. "From the above explanation it will be understood that when it is required to raise or lower the mortise-bar, it is only necessary to turn the

screw-shafts, the rotation of which will cause the nuts of each pair of pendent rods or levers to approach or recede from each other, and thereby increase or diminish the space between the mortise-bar and the framing of the implement, according to the direction of rotation imparted to the screw-shafts; by which means (the level of the hind ends of the hoe-levers being at the same time unaltered) the angle of the inclination of the hoes to the ground will be changed as desired. In order to effect the endway movement of the mortise-bar, which movement is requisite to bring the hoes into a line with their work, a steering-iron is connected to the mortise-bar without any intermediate line or other contrivance, which arrangement gives the attendant increased command over the implement."

941. *Scufflers.*—A scuffler was an implement which was used not only to cut the ground under the roots of surface-weeds between the drills of a green crop, but to pare away at the same time a portion of the sides of the drills. Those effects were produced—the eradication of the weeds, by means of a broad share; the paring of the drills, by means of two flattened curved tines, supported on wings which could be expanded or contracted on a quadrant, and fixed with a pinching-screw, according to the width of the drills. Such a scuffler was something of the form of the drill-grubber, fig. 316, but having the handles attached to the middle bar, at *c*, and with no front wheel. This was a very efficient and pleasant-working implement, but it has somehow of late got out of use.

942. Another species of scuffler, for the same purpose as the one above, was formed of the double mould-board plough, fig. 274. The mould-boards were removed and wings attached in their place, movable on a quadrant, and a broad share affixed instead of the narrow-pointed one. The wings supported either curved tines, as in the implement described in 941, or such as are represented at *b*, fig. 336. This scuffler was abandoned upon the correct principle of avoiding the use of the same implement for performing two very different sorts of work, such as double mould-board ploughing and scuffling.

943. Section Fifth.—*Sowing Machines and Manure-Distributors—The Broadcast Sowing Machine.*—This machine has now come into pretty general use, especially in those districts where the arable system is under the best management, and on large farms is nearly superseding the process of hand-sowing. It not only sows all the white grains, wheat, barley, oats, when sown broadcast, in a very uniform manner, and with any desired allowance per acre, but it serves in a superior manner for grass-seeds, in point of distribution, and, in the case of windy weather, is greatly superior to hand-sowing. This last advantage arises chiefly from the low position of the discharging orifices, as compared with the height of the *hand* in sowing; but partly also from the more direct discharge of the seed from the machine; its velocity of discharge likewise, and the distance it has to fall, being always uniform. The nice gradation of the discharge is one of its chief qualifications, for it may be adjusted to sow any required quantity per acre, between the lowest and the highest, that may be judged expedient, and in all cases, from the uniformity of the distribution, a considerable saving in seed may be effected.

944. We have had occasionally to notice the rather curious facts of the introduction of certain practices from England into the Scottish system of farming. Such practices have either remained stationary in the former country, or have been but partially extended, whereas the practices thus borrowed by the latter have been improved on, and widely extended. The machine now under consideration is another example of this; for though it appears to have been origin-

ally brought into Scotland from Yorkshire, we believe it is even now but sparingly used in England, while in Scotland it is in extensive use in the best arable districts, and still rapidly extending. In the course of some inquiries as to the period when this machine was first adopted in Scotland, we have been enabled, through the kindness of Mr Scouler, late of Haddington, to fix the time of its introduction to the year 1817, and the first machine so made appears to have been by Mr Robert Lowrie, Edington, who makes the following statement:—"The first broad-cast sowing-machine that came into this county (Berwickshire) was ordered by myself from England from Mr Short of Chiverton by Hackhill; it was a smart thing, wheeled by a man, and was about 8 feet long; it is still in the possession of Mr Wilson, Edington Mains. I got that machine in 1816, and in the following year I made one from it for Mr Wright, late tenant in Prenderguest, which was 15 feet long, and was drawn by one horse. So far as I know, this was the first sowing-machine made in Scotland; and after it had sown Mr Wright's crop of that season, I exhibited the machine at the agricultural shows of Coldstream and Kelso, and received premiums for it at both places; this was in 1817; and in the following year I made one of the same dimensions for Mr Wilson's father, the late Mr Abraham Wilson." From Berwickshire the machine made its way immediately into East-Lothian, where the manufacture of it was taken up by the late Mr Adam Scouler after the machines of Mr Lowrie above referred to, and was successfully carried on by his successors, Messrs Scouler and Company of Haddington. The machine here referred to as having been brought from Chiverton, is the same as those yet to be found in the northern and eastern counties of England, and used chiefly for sowing grass-seeds; its application to the sowing of grain having made little progress, or it may rather be considered as having been superseded by the drill-system of sowing, so much practised in these counties.

945. In the early application of the broad-cast machine, it was mounted on two wheels; but a few years' experience pointed out the advantages of a third wheel, which was applied to it by Messrs Scouler about the year 1830, the third wheel being applied as a swivel or fore-carriage. The carriage is still subject to considerable variety of construction, but these varieties are not of a nature to alter its general character. A carriage of a nearly triangular form is very generally adopted, the apex being in front over the swivel-bar. A rectangular carriage is also very much employed, and this is the most workmanlike construction, though perhaps not the cheapest, but it is withal the most convenient and useful form. As regards the general construction, an important improvement has been introduced within the last six years; this is, the cutting of the seed-chest into sections. The chest is usually made 18 feet long, which being far beyond the width of any field-gate, produced a necessity for changing the position of the chest when passing through a gateway. It was therefore the practice to lift the chest from its working position parallel to the axle of the machine, and deposit it parallel to the horse-shafts until it had passed through the gate. This was clearly both imperfect and inconvenient, and these defects gave rise to the cutting into sections, the middle part being 9 feet, and the extremes each 4½ feet, so that when the latter are folded up, the extreme length of chest is 9 feet.

946. In many parts of the country, ridges are made only 15 feet in width instead of 18; but in that case the difficulty of finding access through a field-gate is as great as in the other, so that the division of the seed-chest into compartments is a convenience appreciable by all who use the machine.

947. The illustrations of this machine which we have here given in Plate

XIII. are taken from those manufactured by A. & G. H. Slight of Edinburgh, and they exhibit the machine in its most complete state, embracing the chest in sections, with the mode of supporting the same; this last improvement having, it is believed, been first introduced by the late Mr Slight. In Plate XIII., fig. 1 is a view in perspective of the entire machine as it appears when in work, and fig. 2 a section, on a scale of ½ an inch to a foot, taking the chest transversely through its centre, the carriage being cut in the same line, or parallel to the horse-shafts. In these two figures the same letters mark corresponding parts. The carriage is marked *a b a*, fig. 1, and is a frame of hardwood, the bars of which are from 4 inches to 5 inches in depth, and 2½ inches in thickness; the dimension of the frame being 7 feet in breadth over all and 4 feet in length over the rails, of which there are three, as seen at *b b*. The hind wheels *c c* are 34 inches in height, generally formed with cast-iron naves, wooden spokes and fellies; or, as in the figure, the fellies are superseded by a simple hoop of malleable iron 2½ inches by ⅜ of an inch, which, for light carriages of this description that never travel on hard roads, is found sufficiently serviceable. The axle of these wheels is 1¼ inch diameter, seen at *d* in fig. 2, and is in two lengths supported in pillow-blocks bolted to the lower edge of the bars *a a a*, fig. 1, of the frame, and meeting in the middle bearing. The nigh-side wheel is fixed dead upon the axle, carrying the axle round with it to give motion to the pitch-chain *d e* of fig. 2, and which is seen also at *a* in fig. 1, where it is seen as entering the chest. The off-side wheel may in this case be also fixed dead upon the other half of the axle, or it may run loose. But the axle may also be made in one piece, the off-side wheel being left loose, which is necessary for the convenience of turning round, this wheel being disengaged from turning with the other. The front wheel *f*, fig. 2, and seen also partially in fig. 1, is 24 inches diameter, usually of cast-iron, and is supported on the cast-iron sheers *g*, which are 4 inches wide between the arms, and terminates upward in the lower half of the swivel-plate *h*, and this again is furnished with a strong pivot, passing upward through the head *i* of the cast-iron fore-beam *i k*. The head of the fore-beam is formed into a swivel-plate corresponding to that of the sheers *g*, and is bolted to the two foremost bars *b b* of the carriage. Two small pillars *l*, are cast upon projecting ears of the swivel-plate of the sheers *g*, and bolts passing through these pillars and the splinter-bar *m*, bind these parts firmly together, producing an effective swivel-carriage. The horse-shafts *n*, fig. 1, broken off in fig. 2, are attached to the splinter-bar *m* by means of a long draught-bolt passing through the ends of the shafts, and through eyes fixed in the splinter-bar.

948. The *seed-chest o o*, fig. 1, Plate XIII., is 18 feet in length, formed of ⅞-inch deal. The breadth of the bottom board is 6½ inches, projecting on one side 2½ inches, forming an apron on which the seed falls from the orifices. The sides of the chest are 10½ inches in depth, and the cover 14 inches in breadth, 9 inches of which forms a hinged flap, as seen in the figure. The chest is bound together upon ends and partitions of hardwood 1¼ inch thick; when in sections as here described, each section has two such ends, and the middle section has two partitions in the middle, set at 2½ inches apart. When the chest is in one length, two ends and the two middle partitions only are required. The joints or hinges of the sections are formed of the iron straps *p p*, two of which are securely riveted on each side of the chest, having eyes formed at the apex *q q*, and through these eyes a small bolt *q* passes from side to side, which completes the hinge; and by withdrawing the bolt the parts of the chest are at once disengaged. For the better connection of the segments, however,

when the machine is in action, the contiguous ends are held in contact by a bolt and nut, as seen at c' in fig. 3, which, together with fig. 4, is on a scale of 1 inch to a foot. The two extreme segments also are supported by the light tension-chain $i'' \, i' \, i' \, i''$, fig. 1, which passes over the two upright iron stanchions $k \, k'$, the tops of which $i' \, i'$ form the suspending fulcra for the chain, while its extremities are secured at the points $i'' \, i''$ with adjusting nuts.

949. The *sowing-gear* of the machine consists of the following parts: The main axle of the carriage is mounted with a pitch chain-wheel 4 inches diameter, placed upon the axle close to the middle bar *a* of fig. 1, Plate XIII., and seen in full at *d e*, fig. 2; a corresponding wheel *r* is placed upon a short axle within the seed-chest, and between the two middle partitions of the chest. In this way motion is communicated from the carriage wheels *c*, and their axle to the axle of the small wheel *r*, fig. 2. A light shaft, ½ inch square, is coupled to the ends of the axle of the wheel *r*, extending to each end of the chest: when the chest is entire, each of these shafts is also entire; but in the present case each shaft is in two pieces, coupled at the junction of the segments of the chest by means of small clutch couplings attached to the ends of the shaft, and these engage or disengage of themselves when the segments of the chest are let down or folded up. These last-mentioned shafts are supported in bearings of hardwood laid in the bottom of the chest, at distances of from 2 feet to 2½ feet, and the journals, which are 1½ inch long, covered with straps of stout hoop-iron. The shafts are armed with the seed-wheels of the form shown at *r* in fig. 3, which are placed upon it at distances of 6½ inches, 32 wheels being required for an 18-feet chest.

950. The *sowing-gear* of this machine has undergone a variety of changes. In the example before us, the pitch-chain is employed to communicate motion from the first mover—the carriage-axle—to the seed-wheels. It has the property of great simplicity, but has been objected to on the score of its keeping the seed-wheels constantly in motion, whether sowing or not, which has been supposed to have a tendency to injure the grain that lies in contact with the wheels. Perhaps there may be grounds for this supposition; but if it do exist, the deterioration must be very trifling. Be these surmises what they may, they have given rise to the means of prevention, by employing a gearing that disengages the seed-wheels from the first mover when the machine is being moved, and no discharge of seed required. Fig. 5, Plate XIII., represents a very perfect and convenient arrangement of this kind, and which has been very successfully employed, but is a little more expensive than the chain-gearing: *a* is the seed-chest, *b b* a part of the carriage, and *o o* the middle and back transverse-bars of the same (corresponding to *b b*, fig. 1). The bar *f e*, fig. 5, forming one side of light cast-iron sheers, is bolted to the bars *o o* (standing in place of the middle longitudinal bar *a* of fig. 1); and the three equal wheels *c c c*, fig. 5, are set in the sheers—the first of the three being upon the carriage-axle, and the meeting-ends supported on the sheers. The last of the three wheels *c* takes into the wheel *h*, mounted on the central portion of the seed-wheel shaft, as before described in (949); and *d* is a fourth wheel, of equal size with *c c*, mounted on the lever *g*, which is forked to receive the wheel *d*, and to embrace the sheers parallel to the bar *f e* at *e*, upon which last point the lever turns as a fulcrum. It will be evident that, by lifting the lever *g*, and throwing it forward upon the seed-chest, the wheel *d* will be ungeared from the first wheel *c*; and though it remains in contact with the middle wheel *c*, no motion will be communicated to the seed-wheels, until the lever is returned to its original position.

951. The *seed-wheels* have suffered a variety of changes: originally, circular brushes were employed; then came wooden naves, of about 3 inches in length and $2\frac{1}{2}$ inches in diameter; and into these were inserted leaves or teeth of hoop-iron, about 1 inch broad and 1 inch long, and this form of wheel is still much employed. In the progressive stages of the machine, it was furnished with one set of these small shafts carrying brushes, and another set carrying wheels, as above described; the former being then thought necessary for sowing grass-seeds, and the latter were employed for grains: observation shortly pointed out that the toothed wheels were equally well adapted for either grass-seeds or grain, and the brushes have consequently been laid aside. The wheels represented by *r*, fig. 3, are of cast-iron, of very light fabric; they are ten-toothed, and are $4\frac{1}{4}$ inches diameter, measuring to the extreme points in the cross section; the points of the teeth are slightly rounded to adapt them to the concave groove or cup that is formed in the back of the chest around each discharging orifice; the wheels are cast with a square eye, and fixed upon the shaft by barbing the angles of the shaft round the eye of the wheel.

952. Corresponding to each seed-wheel, a *discharging orifice*, *s*, fig. 3, Plate XIII., is formed in the back of the chest; these are $\frac{7}{8}$ inch diameter, and their centre is $1\frac{1}{2}$ inch above the apron-board *f u*. On the inside of the back-board, oval excavations are made in the wood around the orifices, leaving the bottom of the cups or edges of the orifice not exceeding $\frac{1}{16}$ inch thick; and in this oval cup the seed-wheel sinks until the point of the teeth are only $\frac{1}{8}$ inch clear of the bottom of the cup or the edges of the orifice as seen at *s*, fig. 3. The position of the seed-wheels in relation to the bottom *f u* of the chest, is such as to make the teeth turn at about $\frac{1}{4}$ inch clear of the bottom. The seed orifices are defended by the iron plates *d'*, fig. 4, of a triangular form, the apices *d'* are driven into the apron which secures that point of the plates, and the other two points are fixed by nailing. The fixing of the plates requires some attention, in order that the orifices may exactly coincide with those of the slide *t t*: without perfect coincidence in these two parts the sowing will be unequal.

953. The *slide* is a bar of hoop-iron 2 inches in breadth, and about $\frac{1}{12}$ inch in thickness; it is perforated at the regular distance by means of a punching instrument, and gauged to determine the precise intervals. In the entire chest, the slide is in two lengths, but in that now described each half is again cut in two at the junction of the sections, and connected by a slip hinge-joint. The slide is held in its place by the small clasps *e' e'*, fig. 4, Plate XIII., and a clamp *f* is riveted upon it at any convenient point; the short arm of the lever *w* enters an opening in this clamp, while its fulcrum lies in the plate *b'*, which carries a perforated stud, and is fixed on the back of the chest, as in fig. 3, forming the fulcrum of the lever, by means of which the slide is moved over the seed-orifices. To effect the precise adjustment of the orifices, the slide is made in two halves, and at each end of the chest an adjusting-screw *v*, fig. 1, acts in a nut attached to the end of the chest, the point of each screw being brought to bear against the end of the slide, which is here thickened to meet the point of the screw. The adjustment will be understood by reference to fig 4, which represents a portion of the slide of the left-hand half of the chest. The slide is here supposed to have been pushed towards the right hand by means of the adjusting-screw *v*, fig. 1, till the orifices have been reduced to the desired size, as here shown in fig. 4, about half shut; in this state the machine is supposed to be fit for sowing, and that it has reached the end of the field, when it becomes necessary to shut while turning: the shutting

is effected by moving the slide still further to the right hand, by means of the lever *w*, until the orifices are entirely closed. Both ends of the chest having undergone this operation, which is done in an instant, but in reverse directions, the machine may go to any distance without discharging a grain; but whenever it has been turned into the next ridge, the lever *w* is thrown in the opposite direction, moving the slide towards the adjusting-screw *v*, fig. 1, and this being done at both ends, the orifices will have attained precisely the same area as before, and thus the shutting and opening again to the same area; and of course the same discharge is effected for any number of turns without the smallest variation, so long as the screw *v* remains unaltered.

954. For the purpose of equalising the distribution of the seed over the surface of the ground after it has left the discharging orifice, the *bottom-board f u*, fig. 3, Plate XIII., of the seed-chest is made to project beyond the back of the chest about 2½ inches, as at *u*, forming an *apron* on which the seed is first received from the orifice, and being thus checked in its descent, is thereby more uniformly scattered over the surface. Another precaution is taken, the better to secure a uniform discharge, in the case of sowing on ground that has a high inclination. In sowing up-hill, in such situations, the weight of the seed is thrown more upon that side of the chest from which it is discharged, tending thereby to increase the discharge. On sowing down-hill, on the other hand, the effect of pressure is reversed, and the discharge will be less. To obviate these inconveniences, Messrs Scouler, amongst their other improvements in this machine, introduced a *tilting motion* to the seed-chest in the following manner: on the two outward bearers *a a* of the carriage-bolsters *y y*, fig. 1, having a semicircular seat of about 8 inches diameter, and corresponding to these, on the bottom of the chest, are formed two circular bearings or journals *y y*, fig. 2, on the bottom of the chest and concentric with the shaft of the seed-wheels *r*, fig. 3. Upon these journals the chest can be tilted to a certain extent backward or forward, and this is effected by the lever *z*, figs. 1 and 2, which may be variously attached to the chest. In the present case it is a fork thrust into two apertures in the chest, forming a lever, whose arm is retained in the sheers of the quadrant *a′*, fig. 2, and by raising or depressing the lever *z*, the chest is tilted backward or forward as the sower sees it necessary; the lever being retained in the required position by a bolt passed through the lever and the then corresponding hole in the quadrant.

955. As the seed-chest is 18 feet in length, and it may sometimes be desirable to reduce its breadth of sowing to 16 or to 15 feet, suiting ridges of these breadths, the reduction is effected by stopping two, three, or more of the seed-orifices at each end. For this purpose, the orifices intended to be stopt are provided with a flat swing-clasp, turning upon a pin to which it is riveted, and having a flat tail which is brought over the orifice that is to be stopt. Two of these clasps are seen at each end of fig. 1, Plate XIII., under *x*, where they are in the position that leaves the orifice open.

956. In using the broad-cast machine, it is frequently drawn by one horse; but it forms a rather heavy draught, and is, therefore, more frequently the work of two horses. The chest is filled from end to end with the seed-corn, and, the horses walking in the furrow, the machine sows the half-ridge on either side. When the chest has been filled, and the machine brought to that position which places the horses in the furrow—the sower having previously determined the degree of opening in the orifices that will deliver the desired quantity per acre—he throws each slide outward against its graduating screw, which will produce the proper opening (953); and this done, the horses are driven forward. On

arriving at the farther end of the ridge, and before entering upon the head-ridge, the slides are withdrawn towards the centre, closing up the vents; the machine is then turned round on the head-ridge, and takes up a position on the next furrow, when the process is repeated, and so on till the field is sown all over, the head-ridges being the last portion of the work; and here the blindings of the extreme orifices come frequently into play, if the head-ridges are of less breadth than those of the field. One horse is sufficient in this machine for sowing grass-seeds.

957. It has often been suggested that a register screw or index would be a useful appendage to the machine, by which the sower could at once fix upon the extent of opening in the seed-vents. This addition, however well it may appear in theory, appears, in the practical application of the machine, to be of little value; for the eye of an experienced sower will, on passing over a few yards with the machine, by simple ocular inspection be able to judge of the quantity of seed he is bestowing upon the soil. If experimental accuracy is required, the sower may then put into the chest as much grain as will just cover the seed-wheels, and then *measure* in, one or two bushels, and proceed to sow this until as much remains as will just cover the wheels again, so that the measured quantity is found to have been discharged. By now measuring the number of yards in length that have been sown with two bushels, he will ascertain by calculation the proportional quantity required for an acre. Thus, let the intended quantity to be sown upon an acre be 5 bushels, and that 1 bushel has been sown in the experiment which has covered 140 yards of the 18-feet ridge, or 2 half-ridges equal to 18 feet, or 6 yards. The imperial acre contains 4840 square yards, and this divided by 6, the yards in the breadth of the ridge, we have $806\frac{2}{3}$ as the number of lineal yards in length of an 18-feet ridge to make up an acre; and $\frac{1}{5}$ of this, or 161.2 lineal yards, is the extent that should have been covered by 1 bushel of seed-corn. The machine having, as supposed, covered only 140 yards, it follows that the sowing is about $\frac{1}{8}$ part of the bushel too thick: the graduating-screws, therefore, must be turned forward about half a turn, and the experiment repeated if thought necessary. It is seldom, however, that such experiments will be required in the hands of a practical sower.

958. With reference to the inconvenience attending the great length of seed-chest, as already taken notice of, when it is one length, there remains to be observed that the method by which it is shifted is this: in its working state the chest is kept in its roll-bolster by means of two quadrants attached to the lower part of the chest—one being on each side of the carriage. These are formed concentric with the curvature of the bolster *y y*, fig. 2., Plate XIII., and a bolt over which the quadrant slides is screwed into the side of the carriage, and this retains the chest in its place. When it is found necessary to move the chest, the two bolts are unscrewed, which sets the chest at liberty; it is then lifted from its bolsters and laid longitudinally on the carriage. In this operation the pitch-chain, when that medium of power is employed, has to be disengaged by withdrawing a coupling-link from the chain; but where the medium, fig. 5, is employed, there is nothing required but the unscrewing of the quadrant-bolts to set the chest at liberty, after which it is lifted and laid longitudinally on the carriage. The price of these machines varies from £10 to £12.

959. Smaller, and of course lighter, machines than the one just described for sowing grass-seeds and grain, might be made to move upon two wheels, and be drawn by a man or two men, for the use of small farms.

960. *Grain Drilling-Machines.*—The introduction of the drill-system into the

agricultural practice of any country, will always form an era in the annals of its agriculture; but it is often a difficult matter to define the precise time of its introduction, more especially when we find that, by tracing the history of man in his social capacities, the practice of drilling grain extends backward to the most remote antiquity. A curious and interesting example of this, in an antiquarian point of view, is to be seen in the series of Hindoo models of agricultural implements that was, until lately, in the Museum of the Highland and Agricultural Society at Edinburgh, but now in that of the Technological Museum. Amongst them is to be seen a correct model of a rudely-constructed drill-machine, possessing all the essential points of the more elaborate modern implement; and amongst a people so little liable to change, there can be no doubt that the machine is of very remote origin, compared with which the earliest of our modern drills are but things of the moment; and all of them, of whatever degree of merit, are but improvements on the Hindoo original.

961. Amongst the early notices of the introduction of the drill system in England, we find Amos* recommending it as early as 1783 as the result of numerous comparative experiments; and the figures which he gives of the drill sowing-machine, which he recommends not as an original invention, but an amplification of that given by Duhamel, is almost identical in every essential point with the most approved drill sowing-machine used in the present day in England, and which may be held as the most perfect machine of its kind; but from the excessive elaboration employed in its construction, its high price lays an interdict upon its introduction into the economical practice of Scotch farming.

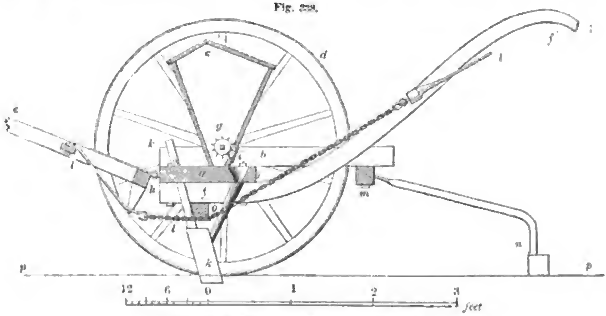
962. The mode of distributing the seed adopted in the broadcast sowing-machine, from the simplicity of the principle, opened a ready means of acquiring a drill sowing-machine at a moderate price: this accordingly quickly followed the introduction of the broadcast-machine, and until very lately no change of importance has been made upon the common Scotch drill. Slight modifications, however, had been effected occasionally, such as varying the distance between the rows, the machine always covering the same breadth, but varying in the number of coulters. Thus, a machine to cover 7½ feet in breadth could change the number of its coulters from 11 to 10, 9 to 8, the spaces between the rows being respectively, 8, 9, 10, and 11 inches, or thereby.

963. *The Common or East-Lothian Drill Sowing-Machine.*—This has been here taken to illustrate the principles of the machine. Though it may be deficient in some points as compared with those of Berwickshire and Roxburghshire, yet its extreme simplicity and cheapness have brought it into very extensive adoption, not only in East-Lothian, but in other districts where the drill-system is followed. Fig. 1, Plate XIV., is a view in perspective of this machine, and for the better elucidation of its construction, fig. 338, shows the arrangement of the parts in longitudinal section, and for convenience of reference the letters mark corresponding parts in both figures. The figures represent a machine of six rows, which is the size most generally used, chiefly because it can be drawn by one horse; but also in the event of its being employed along swelling ridges, its covering but a small breadth secures a nearly equal depth for the deposition of the seed, which cannot be easily done under the same circumstances if the machine is mounted with a greater number of coulters. But it follows from the peculiarity of structure, the coulters being permanently fixed in position for the depth to which they penetrate the soil, that the machine is best adapted for sowing across the ridges, and hence it is

* *Theory and Practice of Drill-Husbandry.* By William Amos. 1802.

almost invariably worked in that direction, though when worked in the direction of the ridge the breadth covered by the machine is equal to one-fourth of an 18-feet ridge.

Fig. 338.



SECTION OF THE COMMON DRILL-SOWING MACHINE.

964. In the construction, *a* is a bed-plank, 5 feet 1 inch in length, 14 inches in breadth, and $2\frac{1}{2}$ inches in thickness. Across the ends of this are bolted the two side-bars *b*, each 33 inches in length, $2\frac{3}{4}$ inches in depth, and $2\frac{1}{4}$ inches in breadth. These last are crossed by the bar *m m*, bolted to the side-bars, serving a special purpose, to be afterwards noticed; and these four parts form the simple framework of the machine. The seed-chest *c* is 4 feet 8 inches in length, placed between the side-bars *b*, and attached to these and the bed-plank. The chest may be about 10 inches in depth, $2\frac{1}{2}$ inches wide at bottom, and 15 inches at top, with a hinged cover. The chest, so mounted with the seed-wheels and axle *g*, and with side-plate, lever, and adjusting-screw, is in all respects similar to the broadcast machine, fig. 3, Plate XIII., except that, in place of the *apron* on which the seed falls in the broadcast, the orifices deliver the seed directly into a small hopper-shaped aperture formed in the bed-plank, immediately under the orifice *i*, fig. 338. The carriage-wheels *d* are 3 feet 1 inch in diameter; the axle of one of them is seated in a strong bush or plummer-block, and coupled to the small shaft of the seed-wheels, thereby giving them the requisite motion, their revolution coinciding with that of the wheels, and the opposite carriage-wheel turns upon an axle fixed permanently upon the bed-frame. The horse-shafts *e* are jointed to the bed-plank at *h*, and appear broken off at *e*, by strap-and-hook hinges, and the handles *f f* are bolted to the lower side of the bed-plank. The coulters *k k* consist of an iron shank $\frac{3}{4}$ inch square, furnished at the lower end with a pointed sheath of sheet-iron about $\frac{1}{10}$ inch thick; the sides of this sheath being about 3 inches broad and 5 inches or more in height riveted upon the bottom of the shank, which at this place is forged into a wedge shape to receive the sheath. The coulters are fixed at top in mortises cut in the bed-plank, and fenced with plates of iron above and below, where they are secured by means of wedges; and they are further supported by the coulter-bar *o*, seen in section. This bar is bolted under the heel of the handles *f f*, and to it the coulters are attached by eye-bolts. The seed, on leaving the orifices, falls into the funnel-shaped receptacle *i* in the upper side of the bed-plank, from which it passes down the tube *i* into the sheath of the coulter *k*, by which it is deposited into the rut formed by the sheath.

965. From the construction and action of this machine, and the resistance of the soil to the passage of the coulters through it, there is a constant tendency produced by the traction of the horse, when the machine is in action, to elevate the extremity of the handles; and by thus swinging upon the axle of the wheels, the coulters are withdrawn from their action on the soil, and from forming the rut for the reception of the seed. The tendency thus produced, being greater than a man is capable of continuing to contend with, is counteracted by the application of the balance-chain *l l*, as shown in fig. 338, producing a change of direction in the line of draught, and of the point of attachment of the draught. In this machine, the true point of attachment is in the hinge *h*, fig. 338; and the tendency of the draught, when applied simply to this point, is to cause the point *h* to approach an imaginary straight line lying between the horse's shoulder and the point of resistance at lower *k* in the figure, and the effect of this is to bring *h* forward and downward, or to throw lower *k* backward till it lose hold of the soil, thereby destroying the intended effect of the coulter. The counteraction of this is effected by the position of the balance-chain, and its attachments to the machine. The first part of it is a simple rod, fixed to the shafts at *l*, and to the extremity of a pendant attached to the hind bar of the shafts at *h*; the chain then passes under the coulter-bar *o*, and on to the cross-bar of the handles *f f*, as seen in fig. 1, Plate XIV., where it terminates in a handle furnished with a spring-catch, by which it can be hooked under tension, to the cross-bar of the handles *f*; or, by disengaging the catch, the chain hangs loose. When the chain is brought under tension, and the shafts borne up by the horse, the resistance to the coulters is transferred to the back of the horse, through the medium of the chain acting on the shaft at the point *l* and on the pendant *h*, the point of which being below the plane of the shaft, changes the direction of the tractive force from *e h* to *e* middle *l*, and leaves the handles *f* in a nearly quiescent state. The *marker*, *m n*, is another appendage to the machine, which, although not so necessary as the balance-chain, is yet generally applied to this drill-machine, especially when sowing across the ridges. It consists of the bar *m m*, and the marking-rod *m n*. The latter is swing-jointed on a stud fixed in the ends of the bar *m m*, and having a stop on the joint, by which either of the markers can be retained in the position of that on the further side of fig. 1, Plate XIV., or let down, as in that of the nigh side. The use of the marker is to trace a line on the surface of the ground parallel to the direction in which the machine travels, and at a distance from the middle point of the surface covered by the machine equal to the entire breadth so covered; hence, on returning to sow the next breadth, the horse should walk exactly upon the line drawn by the marker. In *sowing* with the machine here described, the distance from line to line will be 4 feet 6 inches; the distance between the rows being 9 inches. The wheels are usually set 54 inches apart, measuring at the point where they rest on the ground; or their distance in any machine may be found by multiplying the number of coulters by the number of inches given to the interval between the rows or coulters; thus six coulters, at 9 inches of interval, give $6 \times 9 = 54$ inches. From the construction of the machine it is found, that when the balance-chain is under tension, the coulters are drawn to the ground, and the handles also drawn downward; but on releasing the chain, which is done at the land-ends and turnings, the conductor must support the handles to keep the coulter from the ground, and in this state, if the handles are let go when the machine is standing, the coulter will pass forward, and the handles will fall to the ground. To prevent this last inconvenience, a crutch is usually appended to the marker-bar *m*,

which, on stopping, is allowed to drop to a perpendicular position, resting on the ground, and thus keeps the machine upon a level. This appendage not being of much importance, is left out of the figure. The line *p p* is the surface of the ground upon which the wheels *d* move. This machine requires two horses to work it.

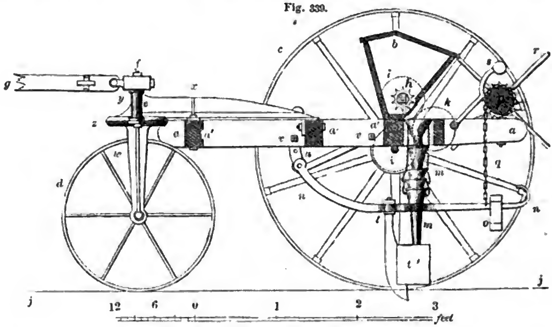
966. This sowing-machine was long and successfully manufactured by the late Scouler and Company, and is now by their successors Kemp, Murray, and Nicholson, of Haddington; and with slight variations by various other implement-makers, as Morton, Leith Walk, Edinburgh; A. and G. H. Slight, Leith Walk, Edinburgh, &c.

967. The price of the common drill-machine varies, according to the number of coulters, from £6 to £10.

968. *New Lever-Drill Sowing-Machine.*—Fig. 2, Plate XIV., represents a drill sowing-machine, introduced by the late Mr James Slight. Mr Slight having been impressed with the superiority of the improved English lever-drills, but seeing at the same time the difficulty, or impossibility, of introducing such an expensive machine into the Scotch practice, was induced to make the attempt of engrafting what appeared the better parts of the English machine upon the more simple machinery of the Scotch, thus producing a machine little, if anything, inferior to the original, at one-third of the price. The results appear to justify the expectations, for the new lever-drill has now been tested in the hands of a number of practical judges, and found to give entire satisfaction, either in sowing grain alone, or in depositing the granulated manures along with the seed in any required proportion. The figures here given of the machine represent it without the manure-chest, which, when adopted, is placed immediately before the seed-chest, making very little change in the appearance, and adding little to the apparatus, except the chest itself.

969. While fig. 2, Plate XIV., exhibits the machine in perspective, the annexed cut, fig. 339, shows more distinctly the arrangement and construction

Fig. 339.



SECTION OF THE NEW LEVER-DRILL SOWING-MACHINE.

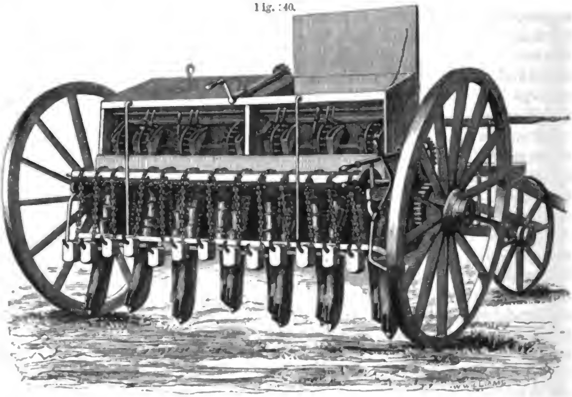
of the parts, by a longitudinal section. In these figures the corresponding parts are marked as far as possible, by the same letter of reference. In the construction of this drill, the bed-frame *a a* consists of two side-rails 5 feet 2 inches in length, 4 inches in depth, and 2¼ inches in breadth, with three principal cross-rails *a'*, fig. 339, mortised into the former, besides a minor rail, forming the bearing or platform of the seed-funnels. The three principal cross-rails are each 4 inches by $2\frac{1}{4}$ inches, the minor rail being only $1\frac{1}{2}$ inch in breadth. The entire width of the bed-frame for a 6-row drill is 4 feet 7 inches over all, and the length over the rails is 4 feet 3 inches. The seed-chest *b*, which is 4 feet 7 inches long, has its sides 12 inches deep, and is constructed and mounted in every respect similar to that of the broadcast-machine, fig. 3, Plate XIII., excepting again the projecting apron, which in the drill-machine is not required, and in the mode of communicating motion to the seed-wheels *h*, fig. 339. The carriage-wheels *c* are 3 feet 6 inches diameter, and have their axle bolted to the lower side of the bed-frame; the wheels may be either constructed in the usual manner with wooden fellies and hooped, or, as in the figure, with a strong hoop of iron only. The fore-wheel *d* is 2 feet diameter, mounted in the sheers *w*, and *e* is one of the two pillars of the swivel-plate, to which the splinter-bar *f* is attached. The shafts *g* are jointed to the splinter-bar *f* by a draught-bolt passing through eye-bolts in the bar and through the ends of the shafts. The remaining parts, *x y z*, of the fore-carriage are precisely the same as described in par. 947 for the broadcast sowing-machine. The *sowing-gear* in the lever-drill consists of a wheel *i* fixed upon the inward end of the cast-iron nave of the carriage-wheel on the nigh side; of a second wheel *k*, placed intermediate between *i* and the third wheel *l*, which last is mounted on a continuation of the seed-wheel shaft *h*; these three wheels are all equal, and are 7 inches diameter. The intermediate wheel *k* is supported upon a stud in the end of a bent lever, the handle of which is seen at the extremity of the side-rail of the bed-frame, and below the roller *p*; by means of this lever the wheel *k* is withdrawn from the wheel *l*, to stop the motion of the seed-wheels. The discharging apparatus of the seed-chest is precisely the same as described in par. 952, with slide *h*, lever *i*, fig. 2, Plate XIV., and adjusting-screw. From the orifice in the slide, the seed falls into funnels *m m*, fig. 339, each funnel consisting of a series of five joints, each joint sliding freely within the one below; the uppermost being fixed on the platform of the bed-frame, and the lowermost in the socket of the lever *n n*. These funnels are made of the strongest tin-plate, and are strung together by three lines of small chain to prevent their entire dislocation, but allowing sufficient freedom of motion to admit of the rise and fall of the lever with its coulter. A quadrant *o*, fig. 2, Plate XIV., of malleable iron, is fixed by the bolts *v v*, fig. 339, on each side of the bed-frame, in such a way as to be capable of a change of position in the vertical direction to the extent of a few inches; to this quadrant the levers *n n* are jointed at *u* upon a rod of iron 1 inch in diameter, which extends from side to side of the bed-frame. The levers are forked at the end *u*, spreading to 9 inches wide, and where the fork unites, the bar is 1 inch by $\frac{1}{2}$ an inch; it is perforated at *t* for the reception of the bar *t t'*, and an eye is formed at *m* into which the lower segment of the funnel is fixed; it then diminishes gradually to the extremity *n*, which is turned up to prevent the weight *o* from being dropt off. The weight is a block of cast-iron of from 3 lb. to 7 lb. weight, of which there may be several sizes, to be applied according to the state of the land, its purpose being to press the coulter into the ground. The coulter in this machine has its cutting edge of solid forged iron, upon which the cheeks *t'* are riveted, forming the sheath, and it is secured in the lever by a screw-nut, while the point of the coulter, sinking 1 inch deeper than the sheath, gives the seed a more pulverised bed than can be produced with a coulter that is level below. A wooden roller *p*, 4 inches diameter, furnished with iron gudgeons and with a ratchet, is supported in a light iron standard at each end, upon the side-bar of the bed-frame. A light chain *q* from each lever is attached to the roller, and a cross *r* being fixed upon the gudgeon at the right-hand side, the roller can thus be turned round by means of the cross-arms, the chains wound up to any desired extent, and the coulters lifted from the ground. This operation is found convenient at the turnings, or at any time when the machine is not sowing, and the roller, chains, and levers are held in the desired position by the pawl *s* falling into the rachet-wheel. The coulters are represented nearly out of the ground, which is indicated by the line *j j*, fig. 339, and when let down to the working level, they penetrate to the depth of 2 or 3 inches. The distance between the wheels, where they rest on the ground, is equal to 54 inches, as in the common drill—one of the wheels, therefore, will always fall into the track of the former round, which may serve as a marker to the conductor of the machine; but, though not shown in the figure, a marking bar, similar to that of the common drill, is usually fitted to it as a movable appendage.

970. From the construction of this machine, with its fore-wheel and with its lever-coulters independently movable, its motions are more steady and its management more easy than the common drill, fig. 338, while the freedom of vertical motion in the coulters gives it the advantage of sowing on any kind of surface, on ridges however round, at equal depths for every coulter, and either across or along the ridges with equal facility. It requires two horses to work it.

971. The prices of the new lever sowing-machines range from £10 to £18.

972. *Garrett's Suffolk Lever Corn-Drill.*—We shall now describe the drilling-machines used in England, of which we select, as an example for illustration, the "Suffolk Lever Corn-Drill," manufactured by Messrs Garrett of Saxmundham, Suffolk. This presents so many features of construction in common with the new lever-drill sowing-machine just described in fig. 339, that we shall have little more to do than describe the arrangements and mode of operation as exemplified in Plate XV.,—fig. 1 of which is a sectional elevation, and fig. 2 an end elevation, both drawn to a scale of ¾ inch to the foot. In fig. 340 we give a perspective view of the machine.

Fig. 340.



GARRETT'S SUFFOLK LEVER CORN-DRILL IN PERSPECTIVE.

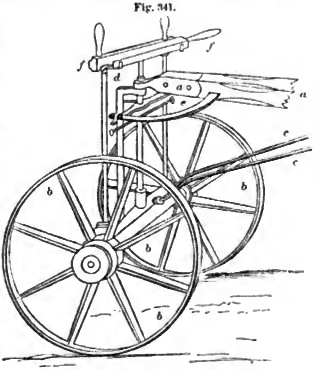
973. In this form of drill the delivery of the seed is effected by a disc *a a*,

fig. 1, Plate XV., attached to a barrel or shaft *b b*, fig. 2, from the face of which projects a series of arms set in a circle. These arms carry cups, which, as the discs revolve in the chamber in which the seed is placed, deliver it to the shoots *c c c*, fig. 2, and which convey it through the delivery-tins *d d* to the coulters *e e*. The depth to which the coulters *e e* penetrate the soil is regulated by the weights *f f* attached to the end of the coulter-levers *g g*, these being jointed at their extremities, as *h*, by the keys *i i*, fig. 1, to the mortise-bar, carried by the frame *j j*. The coulter-levers *g g* being thus jointed at their extremities, the coulters *e e* attached to them adapt themselves to all the irregularities of the surface. The distance between the rows is regulated by setting the levers *g g* on the mortise-bar, carried by the frame *j j*. To prevent damp grain, &c., from adhering to and remaining in the cups, little percussion-hammers are loosely suspended on a bar above the line of revolving cups. As the cups revolve, the arms to which they are attached catch the ends of the hammers and carry them a little beyond the line of their centres. When released from the cup-arms they fall down and strike with a sharp stroke the arm of the cup next in succession, and which at this moment is above the delivery-spout. All adhering matter is then shaken out of the cup.

974. When working on very hard soil, in addition to the pressure exerted by the weights *f f* on the levers *g g*, extra pressure is exerted on them by means of the levers *l l*. The coulters can be lifted out of work by turning the barrel *m* by the lever *n n*, round which the chains *o o*, attached to the coulter-levers, are wound. To keep the corn-box *p p*, the lids of which are shown open at *q q*, in fig. 2, quite level when the machine is going up or down hill, the regulating-screw *r r* is brought into requisition. This is worked through the intervention of the handle *s* and lever *t*, and face-wheels *u* and *v*, fig. 1.

975. The driving-wheels are shown at *w w*, the axle at *x x*, and *y y* are the nave spur-wheels, which engage with the pinions *z* keyed on the shaft *b b* of the cup-barrel. The quantity of seed delivered to the seed-tins *d d* is regulated by the relative sizes of the wheels *y y* and *z z*. Change-wheels are used to vary the quantity of seed delivered as required. Set-screws, 1 1, are used to adjust the different cog-wheels, and keep them properly in gear. The wheels, *z z*, can be taken in and out of gear by the lever 2, fig. 2. The travelling-wheels *w w* are kept clean by the scrapers 3 3.

Fig. 341.



SUFFOLK LEVER DRILL, FORE-STEERAGE—SCALE, ¾ INCH TO THE FOOT.

976. In fig. 1, Plate XV., 4 4 shows the wrought-iron sill which carries the box-barrel and other working parts; 5 5 is the frame of the fore-steerage, 6 6 the steerage travelling-wheel, 7 the connecting-arm by which the steerage is made fast to the frame 4 4 of the drill to steady it in the draught, 8 the iron by which the horses are attached, 9 the friction-break used for steadying the "steerage" in going over rough land. The lever-handle, to keep the steerage straight, is shown at 10.

977. In fig. 341 we give a perspective view of the "fore-steerage." In this view the parts *a a* correspond to that

figured 5 5 in fig. 1, Plate XV., *b b*, *b b*, to 6 6 6, *c c* to 7, *d* to 8, *e* to 9, and *f f* to 10.

978. In using the fore-steerage, the attendant walks behind the wheels *b b*, and by operating on the handles or levers *f f*, adjusts with ease and precision the position of the axle carrying the wheels *b b b*. Two or more horses are required to work this machine.

979. The price of Garrett's Suffolk lever corn-drill is £32; the price of a fore-steerage £4, 10s.

980. *Turnip-Drills.*—Like the other members of the class of implements employed under the drill-system of cultivation, turnip-drills mark an improved state of the art, for in the early history of turnip culture we find the broadcast method of sowing generally adopted, and in some parts of England at the present day, where farming is otherwise well understood, we yet see the broadcast system of sowing turnips not only practised, but advocated as the most productive. That great aggregate weight of turnip may be produced in broadcast in particular soils and seasons, may be true, but doubtless a greater certainty of success is to be obtained from the drill practice; and it appears now, from the latest English authorities, that the broadcast practice will soon be rooted out by the unflinching hand of experience.

981. In the early stages of the drill practice of turnip culture, the breadth of land sown being but small, a single-row hand-drill or barrow seems to have been generally used, but a simpler implement than even this has been employed—the *hand-flask* sower. As the practice extended, machines of two rows were introduced, drawn by one horse, and this in various forms continues to be the chief instrument employed in sowing the turnip-seed.

982. The varieties of the turnip-drill are too numerous to be detailed here in full, nor would it be profitable to follow all the fancies of machine-makers, some of whom have produced but cumbrous and inconvenient vehicles, which, when their purpose is considered, are cumbrous not only in their bulk, but in the multiplicity of their parts, and hence are complicated and tender, liable to derangement and failure, and are marked by an absence of that simplicity of construction so desirable in agricultural *mechanics*. In many of our more modern turnip-drills, however, there is to be seen a marked simplicity of construction that accords well with the objects in view, and this holds especially with those machines which are employed for sowing the seed alone; and in none more so than the machine now very generally known as the East-Lothian drill, which we shall have occasion more particularly to notice.

983. The recent introduction of numerous granulated manures has called forth a new class of machines, whose object is to deposit the manure along with the seed either in immediate contact, or in close contiguity, and these compound machines have again involved a degree of complexity of construction; for whenever a machine is required to perform compound functions, a necessarily increased complication of structure is entailed upon it to a greater or less extent, proportionate, perhaps, to the mechanical talents of the fabricator.

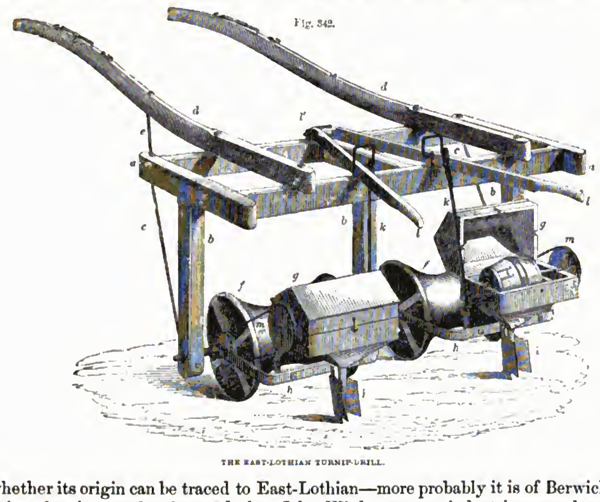
984. An additional cause of complication in the compound drills has arisen within the last few years, from a desire to economise the distribution of the modern expensive manures, by depositing small portions of it at the points only where the future root is intended to grow, leaving the intervals destitute of manure. The propriety of thus dealing so niggardly with the soil in withholding those substances in abundance by which it is enabled to continue its fertility, is at least questionable; but the experiment has effected what we are at present endeavouring to establish—the further complication of structure in

the machines employed. The drill-sowing machines adapted to this purpose are designated in Scotland *plumpers*, from their dropping their gifts on one point. In England they are better known by the name of dibbling-machines, or drop-drills.

985. The whole tribe of turnip-drills may be conveniently divided into two classes, from the manner in which their movements are produced—namely, those that move on *rollers* which press the ridge before the seed is deposited, and those which move on *wheels*, having rollers generally attached as an appendage rather than as a mover. The roller-machines embrace most of those which deposit the seed alone; the wheel-machines chiefly those which deposit manure along with the seed,—but the one-row hand-machines approach to this class, from the necessity of their being furnished with wheels to render their movements more light upon the hand. Without entering fully into the numerous varieties of roller-machines, we shall proceed to give illustrations of only two of its forms, one with an elevated, the other with a low framework.

986. *The East-Lothian Turnip-Drill.*—This drill, represented in fig. 342, is one of the most efficient and simple in construction of its class. It is uncertain

Fig. 342.



THE EAST-LOTHIAN TURNIP-DRILL.

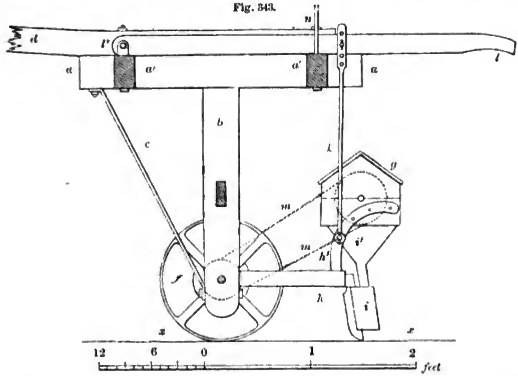
whether its origin can be traced to East-Lothian—more probably it is of Berwickshire; but it must be observed that John Wightman, an industrious mechanic of Upper Keith, East-Lothian, obtained the award of a premium from the Highland and Agricultural Society of Scotland in the year 1827 for his invention or improvement of this machine, and the form adopted by him still continues to be very generally employed, though in some districts with slight variations; but from the simplicity of its construction, and the ease with which it is managed and kept in order, it is not likely to undergo any very important change for the sowing of seed alone. This is an example of a machine with an elevated framework.

987. In describing this turnip-drill by referring to fig. 342, the bed-frame

a a is 4 feet 6 inches long, and 2 feet wide over all, having two transverse and three longitudinal bars, each $2\frac{3}{4}$ inches square. The three pendant or upright bars *b b b* are of the same scantling, and are mortised into the longitudinal bars of the bed-frame; and for additional strength to these pendants, a slot-bar of $2\frac{1}{2}$ inches by 1 inch is frequently passed through them immediately above the rollers, though not exhibited in the figure. Stay-braces *c c* are attached to the bed-frame on the bottom of the pendant by bolts; but in many of the inferior sorts of machines these are omitted, greatly to the deterioration of their strength and durability. The horse-shafts *d d* are bolted upon the two transverse bars; their scantling is usually about 3 by $2\frac{1}{2}$ inches at the front bar; they are also supported by stay-braces *e*, and furnished with the usual horse-mounting. The two rollers *f f*, which are both motive and compressing, were in the early forms of the machine made of wood, but are now made almost always of cast-iron; they are 16 inches in length, 14 inches diameter at the ends, and from 6 to 8 inches in the middle. These rollers are cast as light as possible, and with cross arms at each end, through the eyes of which, and through the lower end of the three pendants *b*, an iron rod of 1 inch diameter is passed, forming the axle of the rollers, and upon which the machine rests and moves. From the varying diameter of these rollers, their surfaces at different points move with different velocities, producing friction and disturbance on the surface of the ridges. To obviate this, it has been proposed to cut the rollers transversely into three sections, thus giving each section freedom to move with its own individual velocity. Two seed-boxes *g g*, one of which is here shown with its cover thrown open, are attached to an iron frame or bow *h*, through the ends of which the axle also passes, whereby the whole becomes movable upon the axle. The seed-boxes *g g* are 12 inches long and 9 inches wide, outside measure, and including the cover are 8 inches high to the apex. The bottom of the boxes is formed of tin-plate funnel-shaped, and terminating in a short nozzle to enter the sheath of the coulter *i*, the latter being also firmly attached to the iron bow *h*. For the convenience of regulating the depth of the rut made by the coulter, and for moving it out of or into the ground, iron connecting-rods *k k* are attached to the seed-box frame, and again at top to the levers *l l*; the latter, serving as handles to the machine, are jointed at *l′*, and when lifted up by the sower and rested upon the iron brackets or guards, by which each lever is embraced, the coulter is raised out of the ground by the ascent of the seed-box frame; and when again set in work, the sower, by holding down the handles till they rest upon the hind-bar of the bed-frame, keeps the coulter at a uniform depth in the soil; the rod *k* being inflexible when once set, but being furnished at top with a plate palm having several perforations, it can be adjusted to any depth of rut that may be judged requisite; hence, in this form of the machine, the connecting-rod *k* is the regulator of depth. The seed-box *g* is only the cover or shield, for the true seed-box, which is usually made of tin-plate, is in form of a small barrel, and is hence called the seed-barrel. The length of the seed-barrel is 6 inches, and its diameter 6 inches; its ends being of hard-wood, and 4 inches diameter, a small axle is passed through the barrel, having bearings on the two ends of the outer box, and upon the outward extremity of each axle there is placed the pulleys *m m*, having an acute groove formed in their edges. A pulley corresponding to each of these is fixed upon the outer ends of the rollers *f f*, and being concentric to the rollers, the main axle passes also through them. A band of strong jack-chain *m* is now passed round each pair of pulleys, whereby the locomotion of the rollers gives a revolving motion also to the seed-barrels, and the consequence is the distribution of the seed through the small orifices in the middle zone of the seed-barrel. An important function of this machine has yet to be noticed—its self-adjustment to the width of the ridges. This is accomplished by the width between the pendants *b b* being greater by 4 or 5 inches than the length of the rollers, together with their attached pulleys and iron bows *h*, which admits of a ready lateral motion of the roller, with its accompaniments of bow, coulter, and seed-box, so soon as the machine is put in progressive motion, and the curved rollers feel any unequal resistance right or left. Any such unequal resistance, on either end of the rollers, draws it immediately to that side where the resistance is felt, until it is fairly adjusted to the slope of the ridge or drill; the effect in this case being produced entirely by the action of the sloping sides of the drill against the conoidal sides of the rollers.

988. Fig. 343 is a longitudinal section of this turnip-drill, for the purpose of showing more in detail the exact relation of the parts referred to in fig. 342, the

Fig. 343.

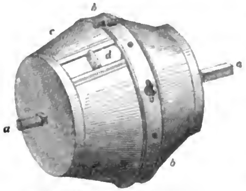


THE LONGITUDINAL SECTION OF THE EAST-LOTHIAN TURNIP-DRILL.

corresponding parts being marked by the same letters as before. Thus *a a* marks one of the longitudinal bars of the bed-frame, and *a' a'* the two transverse bars cut by the section; the pendant bar *b* is shown as it is connected to *a a*, and has also the slot-bar passing through it, and cut likewise by the section. The position of the stay-brace is represented by *c*, with its fixture bolts at top and bottom to the side-bar and pendant, while *d* is one of the horse-shafts broken off. The end of the roller *f* is seen in its position beyond the pendant bar, and *g* gives also an end view of the seed-box, which is fixed between two light bent iron standards *h'*; these are forged in pairs, and are first bolted to the coulter-frame or bow *h*, the seed-box being afterwards affixed between the standards. The coulter and its shield *i* is fixed upon the back of the bow *h*; its length is about 8 inches, the cheeks of the sheath being 5 inches by 3 inches, and standing about 1½ inch wide at the tail. The hopper *i'*, of tin-plate, is fixed in the seed-box as a bottom, the funnel terminating in the spout that conveys the seed between the cheeks of the sheath, and thence into the rut prepared by the coulter in the soil. The connecting-rod *k* is jointed to one of the seed-box standards at bottom, and at top to the lever *l' l*, as before described; *l'* shows the joint of the lever, and *n* is the bracket in which the lever is embraced, and on which it is supported when the coulters are raised out of the ground. The chain *m m* which communicates motion from the roller to the seed-barrel, by passing over their respective pulleys, shown in the figure by the dotted circles, is kept always at uniform tension, whatever be the position of the seed-box, by reason of the bow *h* and its apparatus moving round the main axle of the rollers, when acted upon by the lever *l′ l*. The machine, as here represented, is to be supposed in the act of sowing, the lever *l* being close down upon the transverse bar; the line *x x* therefore represents the line to which the point of the coulter penetrates the soil, which, from the curvature of the roller, will be 3 inches below the surface, the sheath *i* reaching only a depth of 2 inches.

989. Fig. 344 is a perspective view of the seed-barrel, detached from its seat; *a a* is the axle or spindle in which it revolves, and on the longer end of which the pulley is placed. The barrel is formed of tin-plate in two conical frustræ, joined base to base, with a cylindrical band *b* of 1 inch broad interposed between the two, and the truncated ends are closed with discs of hardwood. The band *b* is usually divided into six equal parts, and at each point of division three small apertures are punched out, each three varying in size from $\frac{1}{16}$ to $\frac{1}{8}$ inch diameter, but all in the same order from more to less. A separate band is then fitted to the first, closed with a clasp-joint, and capable of being slid round to a small extent upon the interior band, and is, besides, provided with a pinching-screw, by which it can be fixed at any point within its range of motion, which does not necessarily exceed one inch. The movable band is likewise divided into six equal parts, and at each division a perforation is made larger than any of those in the interior. By these arrangements the movable band can be placed so as to expose any of the three sets of the six perforations of the inner band, whereby a greater or lesser quantity of seed can be sown, according to circumstances. In the figure, the perforations are seen on the outer band; the clasp-joint also is seen near the upper side *b* of the figure; and the pinching-screw and slit by which it can be fixed or moved, are seen in the middle of the figure. The slider *d* covers a hole of $\frac{3}{4}$ inch diameter, by which the barrel can be filled or emptied of seed.

Fig. 344.



THE SEED-BARREL OF THE EAST-LOTHIAN TURNIP-DRILL.

990. In some cases this machine is furnished with a pair of small covering rollers, of 18 inches in length, and 4 inches in diameter, made of any hard wood. When these are adopted, which is but seldom, the rollers are mounted in light iron frames or sheers, which are hooked on to a bolt in the coulter-frame, and are thus dragged behind the machine. These appendages are not, however, considered as forming an essential part of this drill. One horse is quite sufficient to work this machine.

991. The figures given here are from the machines as manufactured by A. & G. H. Slight, Edinburgh, who have also been successful in applying to it an apparatus by which some of the richer granulated manures, such as guano, can be applied along with the seed.

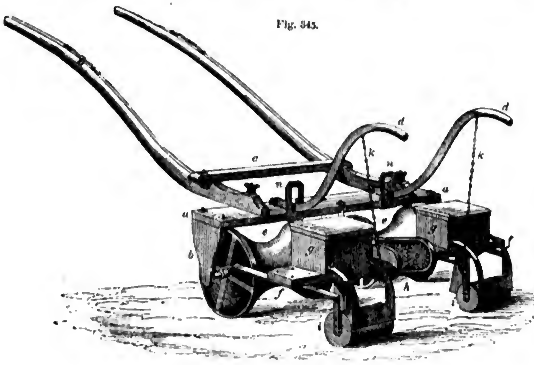
992. The price of the East-Lothian turnip-drill in the ordinary state for sowing seed alone, ranges from £5 to £6, 10s.

993. Several varieties of this drill are to be met with, in which the chief difference lies in the mode of communicating motion to the seed-barrel. In some of these bevelled-gear is employed, in others spur-gear, and in some, examples of both means are applied for throwing the seed-barrel out of motion when it is desirable that the sowing should cease, such as at the turning at the

land-ends, and the like. The want of this in the machines above described may appear as a defect, and, viewing the article as a piece of machinery, it no doubt is a defect; but the advantage to be gained from the adoption of that which may be considered to constitute the more perfect machine is so trifling a saving of seed—perhaps to the amount of from ½ to 1 per cent of the whole—that few farmers seem to consider the saving to be an object of such importance as to compensate for the additional expense and complication induced by the adoption of the disengaging principle. But among these varieties there appeared, some years ago, at the Highland and Agricultural Society's Show at Dumfries, a drill of this class, which, to the adoption of spur-wheel gearing, added a mode of distributing the seed which gave it a claim to notice, and for which a premium was awarded to Mr Geddes, Cargen Bridge, the originator of this improvement.

994. *Geddes's Turnip-Sowing Drill.*—This drill is represented in perspective in fig. 345, and a glance will satisfy the reader that the general principle of its

Fig. 345.

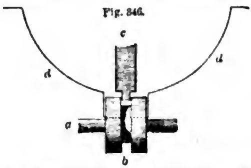


GEDDES'S TURNIP-SOWING DRILL.

construction is the same as that just described—the East-Lothian turnip-sowing machine; but with a depression of the parts forming the framework of the machine, which gives to it an appearance of compactness and strength. A solid plank *a a* takes the place of the bed-frame of the East-Lothian turnip-sowing machine, and a pendant *b* at each end is secured to the plank by means of tenon and bolts; the pendant being no longer than just sufficient to admit the free motion of the rollers under the bed-plank. The horse-shafts *c* are bolted upon the back of the plank, and the handles or levers *d d* jointed to it, and embraced by the open guards *n n*, as in fig. 342. The rollers *e e* are in like manner mounted upon a rod passing through them and the pendant, from side to side, and likewise through a V-form brace of iron appended to the middle of the bed-plank, supporting thus the middle of the rod, which forms the common axle of the machine. The coulter-frames *f f* are applied also on the same principle, but differently constructed; for instead of being a continuous bow, as in fig. 342, they here consist of single bars appended on the axle, and connected transversely by a bed-plank of hard wood, which forms the sole or bottom of the seed-boxes *g g*. The coulter is also attached to this plank, and a perforation formed for the discharge of the seed, which is conducted into the sheath of the coulter by a tube as usual. The arms *f f* of the coulter-frame are prolonged and turned downward to form the bearings of the small covering-rollers *i i*, which, in this case, become permanent members of the machine; and as they must necessarily be used when the land is in different states of dryness, they are each furnished with a permanent scraper, to prevent the accumulation of soil upon them, when it is in a damp state. The motion of the main rollers *e e* is communicated to the seed-distributor by means of spur-gearing in a series of small-toothed wheels, the first of which is attached to the end of its corresponding roller, and the last fixed upon the axle of the distributor; and these, together with the intermediate wheels, are enclosed in a case, one of which is partly seen at *h* with the cover of the case removed. These cases, with their wheels, are attached to and movable with the coulter-frames and all their appendages, and the coulter-frames being supported behind upon the covering-rollers *i i*, these last become the regulators of the depth to which the coulters are to penetrate; and for the purposes of this regulation, the covering-rollers are capable of being shifted up or down in their bearings in the end of the bent arms of *f f*, to suit any required depth. As the consequence of this also, the connection between the coulter-frames and the levers *d d* is formed with a chain in place of an inflexible rod, the levers being required only for lifting the coulters from the ground; while the weight of the frames, with their load of coulters, seed-boxes, wheels, and covering-rollers, possesses sufficient power to keep the coulters in the ground, and the covering-rollers prevent their going beyond the prearranged depth.

995. The distributing apparatus in this machine has been considered to contain its principal merit, and has been supposed to afford a more correct means of graduating the quantity to be sown than the common seed-barrel. This apparatus is very simple; the interior of the seed-box is formed into a semi-cylinder of 7 inches diameter and 5 inches in length, which may be of wood or of tin-plate. Fig. 346 is a transverse section of this, *d d* being the interior surface of the box, in the bottom of which an opening is made to receive a brass roller *b*, $1\frac{1}{2}$ inch diameter, having a groove of $\frac{1}{10}$-inch wide running round it, as in the figure. The roller is mounted on an axle *a*, which is prolonged to sufficient distance beyond the box for receiving the last wheel *h*, fig. 345, of the series already described, the connection with which gives motion to the roller *b*. A slider *c* is attached to the interior of the box, and capable of nice adjustment by a screw or otherwise. The lower end of the slider *c*, which comes in contact with the roller *b*, is formed with a tongue that enters into the groove, and the adjustment of the opening between the point of the tongue and the bottom of the groove determines the quantity of seed to be delivered.

Fig. 346.



THE VERTICAL SECTION OF THE SEED-DISTRIBUTOR OF GEDDES'S TURNIP-SOWING DRILL.

996. The dimensions given of the East-Lothian turnip-sowing machine, fig. 342, will apply generally to this, taking 10 to 12 inches for the breadth of the bed-plank, while its length is the same as the frame of the East-Lothian. One horse works this machine. It is an example of a machine with depressed framework.

997. The price of Geddes's turnip-drill will, in consequence of the greater expense of the wheel-gearing as compared with that of chains, be somewhat higher than the East-Lothian turnip-drill; but the peculiar points here detailed merit the attention of machine-makers.

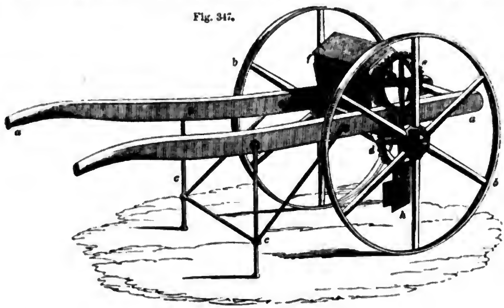
998. *Two-Row Turnip-Drill on Wheels.*—As long since as 1815, a two-row turnip-seed sowing-machine, mounted upon wheels such as those of the New

Lever-Drill, fig. 2, Plate XIV., was in common use in the Border counties of England and Scotland. Why it was given up we cannot tell. Its construction was such, that the handles, the covers of the seed-barrels, and the coulters, were either movable or fixed upon the axle of the seed-barrels as desired. This construction, and the mounting upon wheels, made it a machine admirably adapted for the sowing of turnip-seed upon land in foul condition, in which condition, of course, land should not be, but which it may be in certain seasons. But what is more to the purpose, this construction, with movable handles and coulters and wheels, was best adapted for sowing turnip-seed upon new-taken-in or waste land, which always contains much unbroken turf and other obstacles unsuited to the proper action of fixed coulters and conoidal rollers. This machine formed the foundation of the turnip and bone-dust drill, fig. 1, Plate XVI.

999. Though the cultivation of the turnip can only be carried on to its most productive extent on the large scale, there are yet many who cultivate it successfully on a small one. We therefore give an illustration of a one-row turnip-barrow, suited to farms of small size.

1000. *The One-Row Turnip-Seed-Sowing Barrow.*—This barrow is represented in perspective by fig. 347 : it consists of a frame of timber, formed of the two handles *a a*, connected by a broad transverse bar which carries the seed-box *f*.

Fig. 347.



THE TURNIP-SEED-SOWING BARROW.

The stilts are 5 feet in length, $2\frac{1}{2}$ inches in depth, and $1\frac{1}{2}$ inch in breadth; the width of the frame at the handles *a* is 2 feet, and at the farther point, *a e*, 14 inches; besides the broad bar, a round stretcher *e* to *a* is introduced near the farther point of the stilts, chiefly intended for the attachment of a drag-rope; an iron axle is placed below the frame, running in bushes or small pillow-blocks, and the two wheels *b b* are fitted to it, one of them fixed, the other running free. These wheels are 2 feet diameter, with cast-iron naves, and of very light construction. Two iron legs *c c* are bolted to the stilts, with stretcher and braces to render them steady. A toothed spur-wheel *d*, of 7 inches diameter, is fixed upon the axle, and this acts upon another *e* of equal size fitted upon the spindle of the seed-barrel, which last is of the same construction as fig. 344. The seed-barrel is mounted in the case *f*, and, for the purpose of disengaging the wheel *e* to set the seed-barrel at rest, the slide-bar *g* is applied, which having its upper edge worked into an inclined plane, the drawing out of the slide-bar *g* raises the spindle and wheel *e*, and disengages it from the driving-wheel. The bottom of the seed-box is formed into a funnel, terminating in a director-pipe, as seen near *d*, which descends into the sheath of the coulter *h*. The coulter is simply a bar of hard wood, $2\frac{1}{2}$ inches by $1\frac{1}{2}$ inch, set in a mortise in the transverse bar of the frame, and fixed at the proper position by means of a wedge, and shod at the bottom with a strong sheet-iron sheath.

1001. Two men are required to work this machine, small as it is, one to support the handles, and the other to pull by the drag-rope attached to the round stretcher in front; or a small pony or an ass may be yoked to the stretcher.

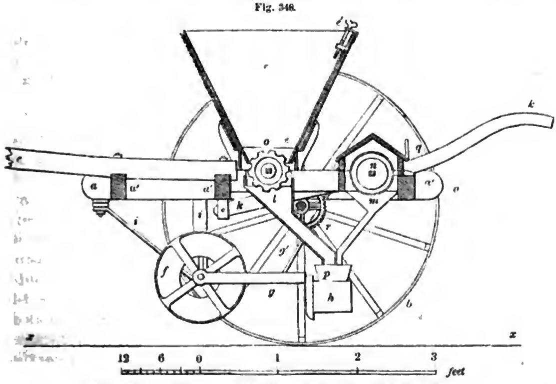
1002. Passing over the many and varied forms of the two-row turnip-drill that are in extensive use, and many of which are very effective, but much too numerous to be detailed here, we proceed to the description of one of those compound machines already alluded to in par. 985, as forming the second class of drills, and which are employed for depositing manure along with the seed in *continuous lines.*

1003. *The Turnip-Seed and Bone-Dust Sowing-Drill.*—The machines of this class have not yet received that general sanction from agriculturists which the first class has long maintained; and this probably arises from the consideration that turnip will and must be sown more or less in all localities, but the kinds of manure to be resorted to will vary considerably, according to the circumstances of those different localities. The simple seed-sowing machine will be employed in all places, but the manure-sower will be resorted to principally in those localities where the granulated manures are more extensively employed; hence the demand for the machines of the complicated class will always be greatly under that of the simple class. The difficulty, also, of producing an efficient compound machine is great, and the expense considerably higher than of those of simple construction, and these circumstances combine to check the extension of those of complicated construction. The machine now to be described is the result of some experience and numerous experiments, in which a variety of arrangements have been experimented upon, and the result has produced a machine that yields satisfaction, and possesses all the requisites of the operation of depositing seed and manure together continuously and in any required quantity.

1004. Plate XVI., fig. 1, exhibits a view in perspective of this turnip and bone-dust drill, but which, from its combination, can only be described in a general way from this figure. The main or bed-frame *a a* is constructed in a similar manner to those of the corn-drills, Plate XIV. This frame is 3 feet 9 inches wide over all, and measures 4 feet 2 inches longitudinally over the front and back rails; the axle of the carriage, which passes across and under the frame, is supported in pillow-blocks bolted to the side-bars. The wheels *b b* are 3 feet 6 inches diameter; one of them is fixed dead upon the axle, carrying the latter round with it, and thus forming the mover of the acting parts; the other wheel being left at liberty to revolve on the axle, for the convenience of turning the machine round. The horse-shafts *c c* are bolted to the two foremost transverse bars, and are made of bent timber, to bring them to the proper height of the horse. The seed-barrels, of the form already described, fig. 344, are enclosed in the boxes *d d*, through which axles pass to and are supported on longitudinal bearers, each axle carrying a pulley, one of which is seen at *d'*. The two manure-hoppers *e e* are 2 feet 2 inches square at the top, 1 foot 8 inches deep, and 8 inches square at bottom. They are constructed with a cast-iron bottom, having an opening of $1\frac{1}{2}$ inch wide, and the length equal to the breadth of the entire bottom, adapted for the reception of the manure-distributing wheel. Flanges *e' e'* rise from the bottom, by which it and the boarded sides of the hoppers are connected, and four ears project laterally also from the bottom, by which it is bolted to the bed-frame. The latest improvement in this machine has been the addition of a pair of pressing-rollers *f f*, of the same form and dimensions as those of the common drill, fig. 342. Each roller is also furnished with a coulter-frame *g g*, which carries the coulters *h h*, the coulter being the only appendage attached in this case to the frame or bow. The rollers and bows are threaded upon a rod as usual, the ends of which are supported in the malleable-iron brackets *i*, one being attached to each side of the bed-frame, with adaptation for being raised or lowered at pleasure. The pressing-rollers have also the usual extent of lateral play, whereby they possess the property of adjusting themselves to the ridges, of carrying the coulter-frame and coulter along with them, and of securing the object of the seed being always sown directly in the middle of the drills. Two lever-handles, *k k*, are jointed to the front bar of the bed-frame, though not seen in the figure; and to these are attached the connecting-rods *f′ f′*, whose lower ends are jointed to the coulter-frame, thus bringing the operation of the coulters under the control of the person who takes charge of the levers *k k*. The connecting-rods *f′ f′* are capable of adjustment, by means of a series of holes in their upper ends; and when sowing, the adjustment is such that, when the coulter is at the proper depth, the lever-handles *k k* rest upon the hind-bar of the bed-frame, and, when thrown out of working, the coulters are raised by lifting up the levers, till they rest upon the bridge *n*. An iron lever is also jointed upon the front bar; its handle, extending backwards to *k′*, serves to disengage the action of the manure-distributors from the motion of the main axle; and as the motion of the seed-barrels is taken from that of the manure-distributors, all the secondary motion ceases on the movement of the lever *k′*, and is again brought into action by moving it in the opposite direction. The motion of the manure-distributor is conveyed by small spur-wheels, which are not seen in the figure, and the seed-barrels are driven by separate chains from the shaft of the manure-distributor.

1005. Such is a general outline of this drill; but in order to make the illustration complete, we have here added a geometrical plan and elevation drawn

Fig. 348.

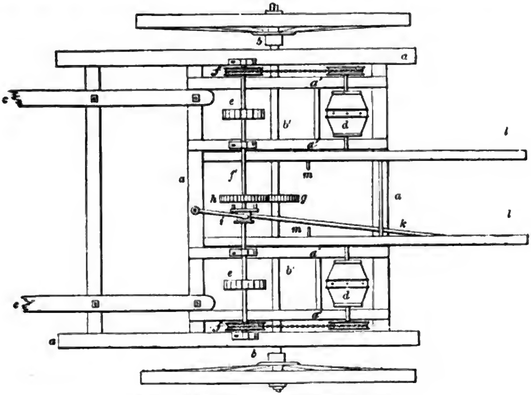


THE LONGITUDINAL SECTION OF THE TURNIP AND BONE-DUST SOWING-DRILL.

to the annexed scale, which thus exhibits the true relation of the parts. Fig. 348 is the elevation, in which *a a* is one of the side-bars of the bed-frame, and *a' a' a'* the three transverse bars; the side-bars $4\frac{1}{2}$ by $2\frac{1}{4}$ inches, the transverse bars 4 by $2\frac{1}{4}$ inches. The carriage-wheels *b* have the axle supported on pillow-blocks bolted to the lower edge of the side-bar *a*, and the horse-shafts, seen broken off at *c*, are bolted upon the upper edge of the two foremost transverse bars. The position of the seed-box is shown at *d*, and *e* marks the position of the manure-hoppers, lower *e* marking also the junction of the hopper with the cast-iron bottom, and the form of the same. While the carriage-wheel rests on the line *x x* representing the bottom of the drill, the relative position of the pressing-roller is shown at *f* with its coulter-frame *g* and coulter *h*, *g'* being the connecting-rod between the coulter-frame and the lever-handle, and *p* a funnel inserted within the sheath of the coulter to retain the manure and seed directors. The pressing-roller axle is supported in the malleable-iron pendant and stay *i i*, which is bolted on at each side of the bed-frame. The lever-handles *k k* are jointed at the fore end in iron sheaves placed under the front transverse bar as at *a' k*, the handle being at liberty to rise and fall as required. A kneed tube *l*, the director of the manure after it passes the distributor, is secured by flanges that lie under the ears of the hopper bottom; it is jointed at *l* so as to have a lateral swinging motion to adapt it to the movements of the roller *f* with its appendage, and it terminates with the funnel *p*. The seed-director *m* is formed in a similar manner, and terminates with the kneed tube in the funnel *p*. It follows from this arrangement, that the seed and manure are deposited in a mixed state, and at the same instant. A seed-barrel of the form of fig. 344 is placed within the box *d*, *n* being the spindle on which it revolves; and *o l* is one of the manure-distributors, being simply an indented wheel of 6 inches diameter, $1\frac{1}{2}$ inch thick, and having ten indentations or teeth; they are mounted on an axle which passes quite across the bed-frame. This wheel is so placed in relation to the opening in the hopper, as to be quite close to the fore end of the opening, while an aperture is left at the opposite side sufficiently large to pass the largest allowance of manure that is to be given out; and in order to graduate this quantity, a sliding sluice *e' e* is attached to that side of the hopper, and is adjusted by means of the screw at top. By these means the area of the discharging orifice can be regulated to any desired quantity per acre. The motions for the discharge of the seed and manure are produced from the wheel *r*, which is placed on the main axle, and gives motion to a similar wheel not seen in the figure, placed upon the manure axle.

1006. In the plan, fig. 349, which exhibits the bed-frame and what is immediately attached to it above, but leaving out the upper works, as well as those below, the parts not seen, or imperfectly seen in the former figures, are here further brought into view. The longitudinal and transverse bars of the bed-frame are again marked *a a a a*, but here four secondary bars, *a' a' a' a'*, are exhibited; these are introduced to form the bearings of the seed-boxes and manure-hoppers with their shafts. The bars *a' a' a' a'*, are mortised into and lipped over the two transverse bars *a a*, their upper surfaces being all upon a level with those of the main side-bars. The carriage-wheels are again marked *b b*, the main axle *b' b'*, and the horse-shafts *c c*, broken off as before. The seed-barrels, with their separate spindles and pulleys, are seen in their position at *d d*, the boxes being removed. The seed-barrel pulleys are driven by means of the chains which pass round the pulleys *f f*, mounted on the auxiliary shaft *f'*, which carries also the manure-wheels *e e*, and the clutch-wheel *h*. This last wheel, which carries round the auxiliary shaft *f'*, runs loose upon the shaft, but can at pleasure be put in connection with the clutch-fork *i*, which slides upon a square on the shaft, and moves at all times with it. The loose wheel *h* is also constantly in gear with the driving-wheel *g*, which is fixed upon the main axle *b′ b′*, and at all times, when the machine moves, keeps the wheel *h* in motion,

Fig. 349.

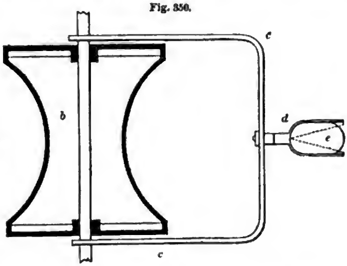


THE PLAN OF THE TURNIP AND BONE-DUST SOWING-DRILL.

while the sowing-gear is at rest. The lever *k* is jointed to the front bar *a*, and has hold of the clutch-fork; this, in the figure, is shown disengaged; but when the whole machinery is required to move, the lever is shifted to the right, which brings the fork of the clutch *i* into contact with the loose wheel *h*, and immediately carries round the clutch, and with it the shaft *f′* and all its dependencies. The lever-handles *l l* are jointed below the front bar *a*, and extend backward to a convenient distance; their chief duty is to lift the coulter, and keep it at a uniform depth in the ground, both of which are accomplished through the medium of the connecting-rods *g′*, fig. 348, which are hooked to the levers on the studs *m m*, fig. 349.

1007. Fig. 350 is a horizontal section of the pressing-roller, with the coulter and its frame; *a* is a portion of the roller-axle, *b* the roller in section, its contour being arcs of a circle. This form, though very generally adopted, is inferior in point of usefulness (especially in giving shelter to the young plants) to that form of roller which has its central part nearly cylindrical, and its terminations two opposite conical frustums, giving to the top of the ridge a surface nearly level to the breadth of 8 inches. The bow or frame *c c* is made of malleable iron, 2 inches in depth, and $\frac{3}{8}$ inch in thickness; *d* is the sheath of the coulter, which for this machine requires to be made wider than

Fig. 350.



THE PRESSING-ROLLER AND COULTER-FRAME OF THE TURNIP AND BONE-DUST SOWING-DRILL.

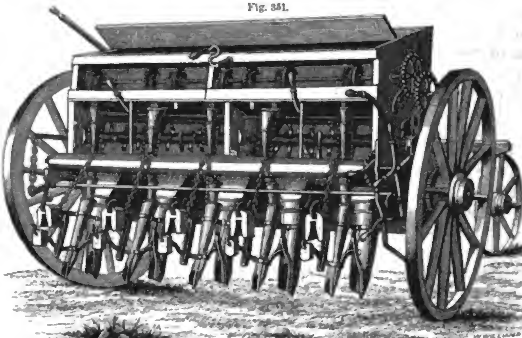
usual to receive the manure-director; the dotted lines at *e* show the width and form of the cheeks of the sheath at bottom. In this case, also, the opening behind in the sheath is closed up by the oval-shaped funnel *p*, fig. 348, the body only of which is here shown, the spreading funnel being cut off in the figure, but distinctly seen in fig. 1, Plate XVI., above *h h*. Fig. 350 shows the bow *c c* as applicable to the seed and bone-dust machine, but the only difference between this bow and that of fig. 342 is, that in it the bow of fig. 342 is made so much wider as to admit the chain *m* pulling between the end of the roller and the cheek of the bow *h*.

1008. The machine thus described may be considered as one of the best of its kind, and though apparently complicated, it is yet as free of that fault as it is perhaps possible to attain, while the essential objects are kept under command. The graduation of the discharge of manure is attainable by it to any desired limit, and the discharge is also regular and uniform. The means of engaging and disengaging both the seed and manure gearing is perfectly efficient and simple. One horse is quite sufficient to work this useful machine.

1009. From the materials and labour necessarily expended in the construction of a machine of the kind of the turnip and bone-dust sowing-machine, the price is higher than that of the common two-row drill, fig. 342, being £11, 10s.

1010. *Garrett's Seed-and-Manure-Sowing Drill.*—We shall now describe Messrs Garrett's seed and manure drill, for drilling every description of seed with or without manure. In fig. 351 we give a perspective view of this machine,

Fig. 351.



GARRETT'S SEED AND MANURE SOWING-DRILL IN PERSPECTIVE.

and in Plate XVII. two views, of which fig. 1 is a sectional elevation, and fig. 2 an end elevation, both being drawn to a scale of $\frac{3}{4}$-inch to the foot.

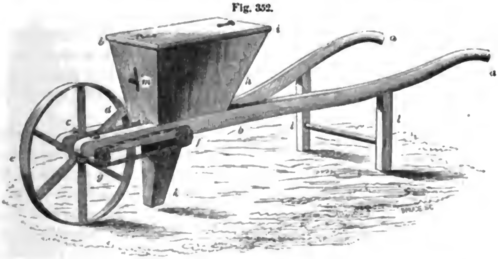
1011. The seed is put into the box *a a a*, fig. 2, Plate XVII., from which it passes through slides, in regulated quantities, into the chamber in which the cup-barrel *b b b* revolves. It is then taken up by the cups *c c* and delivered to the delivery-tins *d d*, and from thence passed to the seed-coulters *e e*; the depth to which these enter the soil being regulated according to the pressure on the levers *f*, fig. 1, by the weights *g*.

1012. The manure is put into the manure compartment, the quantity passing therefrom being regulated by a movable slide worked by the handles *h h*, fig. 2, attached to the wrought-iron shaft or spindle *i i*, this shaft being connected with the joints *j j*. The manure is passed into the manure-delivery tins *k k*, fig. 1, and from thence to the manure-coulters *l*. These coulters are regulated in the depth to which they penetrate the soil by the cross *m m*; fixed on the shaft of the barrel *n*, round which the chains *o o* are passed, their lower extremities being attached to levers *p p*, supporting the weights *q*. Rakes *r r*, attached to the manure-coulters *p p*, fill up the channels left by them, so that the seed-coulters *e* work in fresh-stirred soil directly above the manure.

1013. The manure and seed-box is raised and lowered, so as to be kept level on hilly ground, by the handle *s*, fig. 1, working the lever *t*, and by the face-wheels—one of which is shown at *u*—the screw spindle *v*. To the travelling-wheels *w w*—a number of the spokes, and part of the felly of the nigh one, are broken off to show the wheel-work at 1 *z y*—the nave-wheel *x* is attached; this engages with the wheel *y*, which again engages with the intermediate wheel *z*. This is fixed on the shaft of the manure-barrel, and engages with the wheel 1 fixed on the driving-shaft of the seed-barrel. The manure-stirrers are worked by the cog-wheels 2 2, fig. 2; 3 3 are the wheel-scrapers. The partitions for keeping the seed in regulated quantities in the different compartments of the box are denoted by the figures 4 4 4. The wheel *y* is thrown in and out of gear by the lever 5, fig. 1. The wrought-iron sill is shown at *b b*, fig. 1, on which the box and other working parts are supported.

1014. *The Bean-Sowing Drill or Bean-Barrow.*—This is one of the simplest in its construction of that class of machines which are employed for depositing the various kinds of seeds in the soil in the drill system. The bean-drill is made in a form resembling a wheelbarrow, and hence its name. Fig. 352 is a view in perspective of the machine in its most common form;

Fig. 352.

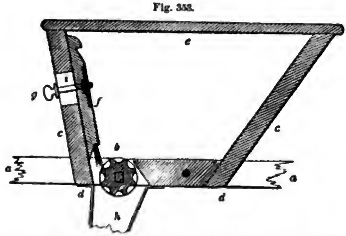


THE BEAN-SOWING BARROW.

a a b c are a pair of stilts worked to a particular curve, that, when joined to form the bed-frame of the barrow, has the portion from *b* to *c* parallel, and about 6 inches wide over all; while the parts from *b* to *a* spread out to a width of 2 feet, forming the handles of the barrow. The body parts *b c* are $2\frac{1}{2}$ inches in depth and $1\frac{3}{4}$ inch in thickness, and are bolted together upon two blocks of $2\frac{1}{2}$ inches in thickness, leaving the portion from *c* to *d* open for the reception of the wheel *e*, and a small space is likewise left open in the body for the reception of the seed-cylinder, which is about 3 inches diameter and $2\frac{1}{4}$ inches in length. A small axle passes through the bed-frame and the cylinder, and this axle carries a small chain-wheel *f*. The principal wheel *e*, which is of very light construction and 18 inches diameter, carries also a chain-wheel *g* upon its axle, of the same diameter as *f*, and the pitch-chain *f g* is stretched over the two wheels, by which means the progressive motion of the machine on the wheel *e* gives motion to the seed-cylinder on the axle of *f*. A seed-chest *b d h i* is raised upon the bed-frame; it is 12 inches long at bottom, and 24 inches at top, and the depth 12 inches—the width over all at bottom being 6 inches, and at top 10 inches. The chest is sometimes covered with a jointed lid, but this is not essential. A spout *k*, formed of sheet-iron, is attached below to the bed-frame, for the purpose of directing the seed to the furrow in which the machine is moving, and the legs *l l* are attached to the handles to prevent the latter from falling to the ground when the barrow is stopped. The pinching-screw *m* is applied to the purpose of adjusting a slider placed within the chest, for the more correct graduation of the discharge; and the slider is for this purpose armed with a tuft or brush of bristles that comes in contact with the seed-cylinder. The entire fabric is generally of very slender and light construction.

1015. Fig. 353 is a longitudinal section of the barrow, on a scale of 1 inch to the foot. *a a* is the bed-frame, broken off at both ends; *b* is the seed-cylinder, occasionally made of brass, but generally of hard wood, which is grooved longitudinally, to receive and carry down the regular discharge of seed. The front and back *c c* of the chest are passed down between the stiles of the bed-frame at *d d*, which secures the chest to the frame; and *e* is the lid or cover of the chest. The slider *f* is mounted with the brush at *b*, its lower end, which, by being made to approach to or recede from the cylinder, diminishes or increases the quantity of discharge; and it is held in any required position by the pinching-screw *g*, which has freedom to move with the slider in the slit *i*. The spout *h* is here shown also as broken off.

Fig. 353.



LONGITUDINAL SECTION OF THE HOPPER OF THE BEAN-SOWING BARROW.

1016. Besides the method here exhibited, of driving the seed-cylinder by means of a pitch-chain (1014), there are other modes of effecting the same purpose. One of these is by attaching short cranks to each end of the axles of the principal wheel and the seed-cylinder, the pair on each axle standing at right angles to each other; and a light connecting-rod passes from the one to the other on each side of the machine. This forms a very perfect communication of the motion from the principal to the minor axle, and is very certain in its operation, but it is more expensive than the pitch-chain.

1017. The same is also effected by employing two pairs of small mitre-wheels; but it is equally expensive as the cranks and connecting-rods.

1018. Common chain may also be adopted, along with acutely-grooved pulleys; but the action of this is less certain than either the cranks or mitre-wheels.

1019. In using the bean-barrow, a man wheels it before him along the bottom of the drills, or that of the common furrow after the plough.

1020. *The Plough Bean-sowing Drill.*—An apparatus for sowing beans in rows on the surface is sometimes employed, attached to one of the ploughs when giving the seed-furrow. It consists of a seed-cylinder, placed in a small case or frame, having an axle passing through the case, which last is surmounted by a small hopper to contain the seed. This apparatus is attached to the plough immediately behind and within the line of the mould-board, having a conductor, or spout, from the seed-cylinder to the bottom of the furrow, to conduct the seed to its bed. The motion of the seed-cylinder for the delivery of the seed, is produced in two different ways. First, the axle of the cylinder may be extended from the case to the land-side handle of the plough, or tail of the beam, where it will have a bearing in which it turns round. Upon this extension of the axle, a light iron loop or sheers is loosely fitted, about 2 feet in length, and in the sheers is placed an iron wheel of 18 inches diameter, whose axle is borne at both ends by the sheers. A grooved pulley is fixed upon the end of this axle, and a corresponding pulley upon the prolongation of the axle of the seed-cylinder, while a chain or band encircles the two pulleys. The iron wheel, which is so placed as to run in the bottom of the furrow, will thus, when the plough is in motion, be made to revolve by its contact with the ground, and, through the pulleys and chain, will also cause the seed-cylinder to revolve and discharge the seed as the plough advances; and this will continue as long as the iron wheel remains in contact with the ground. In order to produce a cessation of the sowing process when required, a cord is attached to the hind extremity of the sheers, and is passed backward between the handles of the plough till it comes within reach of the ploughman, who, by pulling the cord, and hooking it upon a stud provided for that purpose, raises the iron wheel from the ground, and thus stops further motion of the seed-cylinder, and consequently the sowing process. When the plough has again reached the *third* furrow from the *last sown*, the ploughman relaxes the cord, when the wheel again settles down upon the ground, and the sowing process proceeds as before.

1021. The other method of giving motion to the seed-cylinder is accomplished by giving the extension of its axle a universal joint, and continuing the extension a few inches to landward of the land-side of the plough, but without a bearing upon it. Upon this extremity of the extended axle the iron wheel is placed, which in this case will be required of larger diameter, so that the axle may run clear of the tail of the plough-beam. By this arrangement the wheel will run upon the unbroken land. It will also require a stay of rope, or of light iron-rod extending from a collar upon the axle, forward to an eye-bolt attached to the side of the beam, near the coulter-box. From the collar on the axle also a cord extends backward to the hand of the ploughman, whereby he has the same command over the wheel in this position for setting on and off the sowing process, as before described in par. 1020—the universal joint in the shaft serving, in the present case, the same purpose as the sheers in the other.

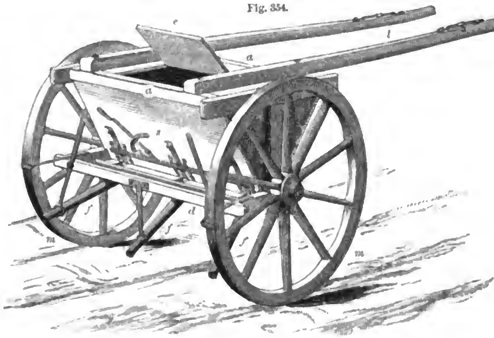
1022. This machine is not suited to sow beans in raised-up drills.

1023. *Kemp, Murray, and Nicholson's Three-Row Bean-sowing Drill.*—This implement is for sowing three rows of beans at one time in the hollows of the drills, which are afterwards covered by splitting the drills with the plough in the usual way. It can sow from 12 to 14 acres imperial in ten hours, according to the number of turnings at the land's ends.

1024. Fig. 354 is a perspective view of the machine; fig. 355 a back view, showing the apparatus for regulating the delivery of the seed; and fig. 356 a cross section. The same letters refer to all the figures. The body consists of a hardwood framework, formed by two T-shaped ends, connected at top by two rails *a a*, and at bottom by a sole-plank *b*, to which the uprights are attached by iron straps, with screws and nuts underneath. Between the upright end-pieces and the sole-plank two short bars *c* are introduced, and project about 12 inches behind the sole-plank to support the rail *d*, into which they are mortised, and which completes the skeleton of the machine.

1025. On the inside of the end parts of the frame triangular boards are fixed to form the ends of the seed-chests, and to these as well as to the upper rails are

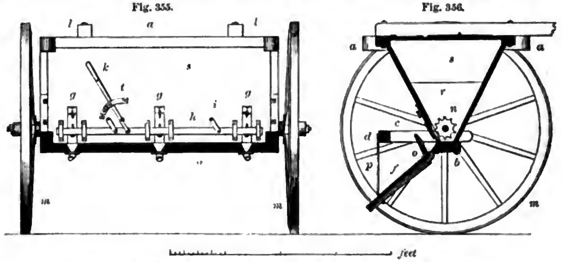
Fig. 354.



KEMP, MURRAY, AND NICHOLSON'S THREE-ROW BEAN-SOWING DRILL IN PERSPECTIVE.

fixed the back and front boards. The cover of the seed-chest is fixed in checks formed on the two rails *a a*, a portion being hinged to form a door *e*, for access to the interior. The axle which carries the supporting-wheels *m m*, and also the

Fig. 355. Fig. 356.



TRANSVERSE AND LONGITUDINAL SECTION OF THE THREE-ROW BEAN-SOWING DRILL.

seed-wheels, runs in bushes sunk into the bottom of the upright end-bars, and passes through from end to end of the seed-chest, its centre being about 3 inches above the sole-plank, which forms the bottom of the chest. There are three delivery-wheels *n* of cast-iron on the axle, each 4½ inches diameter, and 1½ inch thick, with ten semicircular notches formed in the rim, one wheel being in the centre of the axle, and the others at a distance of 1 foot 7 inches on each side. Between these delivery-wheels two divisions *r* are placed, about half the depth of the seed-chest, to divide the lower part into three separate portions, and thereby prevent the seed collecting at one end. One of the supporting-wheels is fixed in the axle to carry it round and work the seed-wheels, the other running loose to allow the machine to turn readily. The seed is delivered through holes in the back of the seed-chest, and falls into small hoppers *o* formed in the sole-plank, whence it passes into sheet-iron spouts *f*, supported at top by cast-iron necks attached to the under-side of the sole-plank, and near the bottom by wrought-iron suspenders *p* attached to the back-rail *d*. The support for the middle spout is fixed, but those for the side ones are movable, to allow the spouts to be set out or in to suit different widths of drills. When the spout is adjusted, the bolt on which the suspender is jointed is screwed tight, and fixes the spout in the required position. A pair of light horse-shafts *l*, with the usual mountings, are bolted on the top of the rails *a a*.

1026. The principal novelty introduced by Messrs Kemp, Murray, and Nicholson, consists in the method of opening and shutting the holes in the seed-chest for the delivery of the seed, and which they are applying to broadcast and other sowing machines that have hitherto been fitted with a plate sliding endways over fixed holes in the seed-chest, this sliding-plate being furnished with holes corresponding to the others. (See *v*, fig. 1, Plate XIII.) The disadvantage of this old method consists in the opening not being always opposite the centre of the seed-wheel; for if central when full open, it must be half its diameter to one side when nearly shut, which cannot but affect the regular delivery of the seed. By the new method the opening, of 1 inch diameter, is made opposite the centre of the seed-wheel, and, as usual, protected by a plate of sheet-iron on the outside of the seed-chest, the wood being cut away on the inside to allow the wheel to come near the hole in the plate. On the outside of this plate, another plate *g*, 9 inches long and 2 inches broad, is made to slide vertically, and fixed to the seed-chest by a pinching-screw. When in its lowest position, a hole formed in it corresponds with that in the first plate, but when drawn up this hole is covered, and thus one or other of the holes may be kept from delivering seed while the others are in action. In front of these sliding-plates is a strip of hoop-iron *h*, 1½ inch broad, and nearly the whole length of the seed-chest; it is supported by staples of hoop-iron attached to the chest, two to each seed-hole, and of sufficient length to allow the plate to be slidden up or down, so as to completely expose or cover the seed-holes, which are thus increased or diminished in the vertical in place of the horizontal direction, as usually practised. The long plate *h* is jointed to the seed-chest by two links of hoop-iron *i*, 3½ inches in length between centres; they are nearly vertical when the plate is in its lowest position, and inclined when it is raised, the links acting like the connections of the common parallel ruler, keeping the plate always horizontal, and consequently opening the different holes equally and simultaneously. Motion is given to the plate by a lever *k*, jointed to it and to the seed-chest; the upper part of this lever works within a fixed quadrant *t*, carrying an adjustable stud, by which the motion of the lever can be stopped at any definite point, and the holes opened to the proper width.

1027. The dimensions of the principal parts are as follow:—The sole-plank *b* is 4 feet 4 inches long, 8 inches broad, and 2 inches thick, and the small hoppers *o* formed in it are 3 inches square at top; they are simply notches 3 inches deep cut in the back edge of the plank, the edge being bevelled so that the application of a strap of wood all the way along forms the fourth side of the hoppers; this piece of wood, which is about 1 inch thick, projects 2 inches above the main plank, to prevent the spilling of the seed in case it should by any accident miss the hopper. The depth of the seed-chest *s* from the sole-plank *b* to the top of the framing *a* is 1 foot 11 inches, the length over the framing 4 feet 4 inches, and the width over the two top rails 2 feet 6½ inches. These rails are 3 inches broad and 2 inches deep; the two end rails into which they are mortised, and which form the heads of the T-frames, are 3 inches square. The upright bars are 4½ inches by 2 inches, flush with the beads outside, to leave room in the inside for the end boards of the seed-chest. These ends are 1 inch thick, and fill up the whole width within the top rails, diminishing at bottom to 3 inches in width. The sides are also made of 1-inch deal, nailed to the ends and the under-side of the top rails. The cover is $\frac{3}{4}$ inch thick, nailed down in checks formed in the top rails, and having a hinged door *e* 2 feet long by 1 foot 4 inches broad in the centre of its length, and close to the hinder rail. The lower rail *d*, which supports the hangers of the spouts, is $2\frac{1}{2}$ inches square, and 4 feet 7 inches long. The supporting-wheels *m* are 3 feet 9 inches diameter, and $1\frac{3}{4}$ inch broad in the tire, the width between the centres of the tires being 5 feet. The axle is $1\frac{1}{8}$ inch in diameter, slightly swelled for the seed-wheels. The seed-spouts *f* are of sheet-iron, $1\frac{3}{4}$ inch diameter at top and $1\frac{1}{2}$ inch at bottom, riveted lightly to the cast-iron neck-pieces at top, and reaching to within about 6 inches from the ground.

1028. The price of this three-row bean-sowing drill is £6, 10s.

1029. *The Drop Sowing-Drill or Dibbling Machine.*—Sowing seed and manure together, not continuously, but in small deposits, has been the object of numerous and varied experiments. The propriety of this mode, and the advantages to be derived from its achievement, seems yet doubtful; but the accomplishment of the mechanical part of the operation is now tolerably well performed by machines of various makers. In the earlier forms of the drop-drill they were found to perform tolerably well when moving at a slow rate, but failed when impelled at the usual rate of sowing. This defect seems to have arisen from the peculiar form of the manure-depositor, which, in these machines, was usually a short cylinder chambered in the periphery, and half encircled by a metal cover, whereby the manure was allowed to drop from the chambers as these came successively from under the cover.

1030. One of the first successful machines of this kind is believed to have been that patented by Mr William Grounsell, Louth, Lincolnshire, in 1838; and soon after they were brought to an equal degree of perfection in Scotland by Mr Sidey, Pitcairn Green, Perth, who still holds by the chambered cylinder, but more correctly encased, so as to drop distinctly with a moderate speed.

1031. The price of Mr Sidey's single machine is about £6; if extended to two rows, the price would not exceed £10.

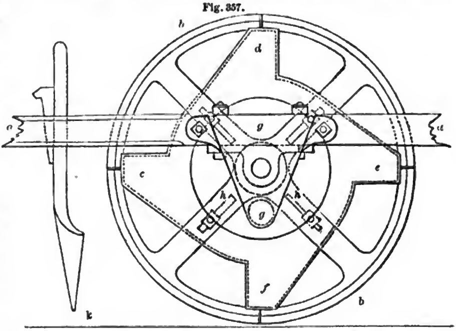
1032. *Smith's Drop-Drill.*—The latest improvement that has yet appeared in Scotland of the drop-drill has been effected by Messrs Smith, St Ninians, near Stirling, who, adopting a combination of the best parts of previous machines, have produced one that seems more likely to attain the desired object than any of its predecessors. In this a metal trunk is introduced for receiving the manure from the ordinary distributing-wheel, and being provided with a *valve* capable of being opened and shut at certain intervals, the manure is retarded in its descent within the trunk by means of the valve, until the requisite quantity is collected, when the valve, being suddenly opened, makes the deposit, and is again shut. It is a single-row drill, is drawn by one horse, and costs £6.

1033. There are apparently some advantages derived from this successive mode of deposit of the manure and seed, especially with those manures that are considered the most active, such as bones, guano; for here the manure is laid in the rut, the earth of which partially falls in and mixes with it, thereby reducing its intensity; and the seed is dropped upon the mixture instead of falling directly amongst the pure matter, as is generally the case with machines that sow both seed and manure continuously. It is said that a more speedy and vigorous vegetation is produced by this than by the continuous mode of sowing; but it may yet be deserving of observation, whether the more speedy development of the young plant does not arise from the circumstance of the seed, under this mode of treatment, being deposited nearer to the surface of the soil than it is when put in immediately behind a coulter; and viewing the subject in this light, it may suggest the question, Whether deep-sowing alone may not be the cause of the protracted vegetation so often and so seriously experienced in the turnip crop? This subject, as regards the turnip crop alone, appears to us deserving of careful experiment not yet undertaken, and, if determined in the affirmative, much disappointment and loss may be prevented by adopting due precautions to insure sowing at a proper depth.

1034. *Chandler's Drop Sowing-Drill.*—Of the drop-drills recently introduced we select that of Chandler's, manufactured by Messrs Reeves of Bratton, Westbury, Wilts. It is shown attached to the lower part of the liquid-manure drill in Plate XVIII. Instead of a coulter which cuts the furrow, a "press-wheel" *a a*, fig. 1, Plate XVIII., is substituted; this works in a lever *b b*, weighted at one extremity by weights *c*, and jointed at the other to a mortise-bar *b′*. A cylinder of cast-iron revolves in the seed-box *d*; in the periphery of this cylinder triangular recesses are cut, into which the seed is deposited as the cylinder revolves. As each recess passes into the open space of the lower aperture of the seed-depositor, the seed contained in it is released, and drops into the furrow made by the press-wheel *a a*. To the end of the cylinder-shaft a pinion *e e* is keyed; this engages with a spur-wheel *f*, which again takes into the teeth of a pinion *g*, keyed in the shaft of the press-wheel *a a*. Motion is thus imparted from the press-wheel *a a* to the seed-cylinder in *d*.

1035. *Chambers's Water Drop-Drill.*—We now give a side elevation of the "water drop-drill" of Mr Thomas Chambers of Fakenham, and which has been successfully brought into practice. It is applicable to any water or liquid manure-drill. In fig. 357 *a a* is part of a mortise-bar carrying the wheel *b b*, which runs in the furrow made by the coulter *k* which precedes it, and which is fixed in the bar *a a*. The axle of the wheel *b b* carries a hollow rotating chamber, from the periphery of which four arms or spouts, *c d e f*, extend. A cap or chamber *g g* conducts the liquid manure and seed from the manure and seed compartment of the drill to which it is attached — as by the funnels *r r*, fig. 1 and 2, Plate XVIII.—to the interior of the chamber rotating on the axis of the wheel *b b*, fig. 357. As the drill progresses, it drags after it the bar *a a* and wheel *b b*, causing the chamber to rotate on its axis; and as each delivery-spout, *c d e f*, comes in contact with the soil, it discharges the seed and manure. If the size of the wheel *b b* remained invariable, the distance between the deposits of seed and manure would also be invariable. To give a capability of varying this distance, the wheel *b b* is made in segments, and the arms slotted and provided with bolts and nuts, as shown at *h h*. By sliding in and out the arms carrying the segments, and fixing them at any

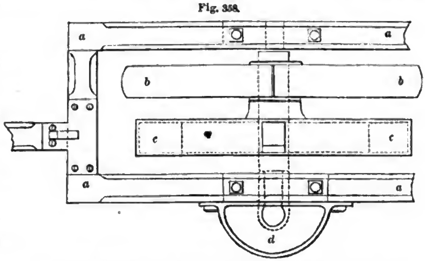
Fig. 357.



SIDE ELEVATION OF CHAMBERS'S WATER DROP-DRILL.—SCALE, 2 INCHES TO THE FOOT.

point of adjustment desired, by means of the bolts and nuts, the diameter of the wheel *b b* may be diminished or enlarged, and the distance between the points of the spouts, *c d e f*, correspondingly adjusted.

Fig. 358.



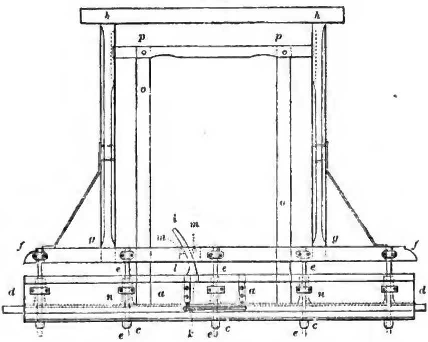
PLAN OF CHAMBERS'S WATER DROP-DRILL—SCALE, 2 INCHES TO THE FOOT

1036. In fig. 358 we give a plan of the apparatus; *a a* the mortise-bar, *b b* the wheel, *c c* the hollow chamber, to which the seed and manure are supplied by the cap *d*.

1037. Messrs Reeve have informed us that they have adopted the form in fig. 358 of the water drop-drill, giving up the use of that described in fig. 357.

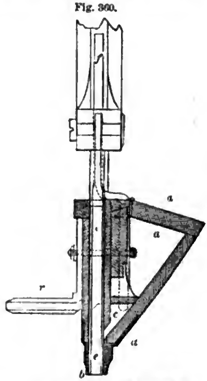
1038. *The Depositor-Dibble or Grain-Planter.*—This implement, known as "Sigma's," and manufactured by Mr Charles Powell, Ticehurst, near Hurstgrove, Sussex, from its simple and ingenious arrangement, we shall notice here. In fig. 359 we give a front view, and in fig. 360 a transverse vertical section. The trough or seed-box *a a a*, fig. 360, is angular in form. In front of this, five perpendicular holes or vertical chambers, as *b*, are placed; communicating with these vertical

Fig. 359.



FRONT VIEW OF "SIGMA'S DIBBLE"—SCALE, 1 INCH TO THE FOOT

Fig. 360.



TRANSVERSE VERTICAL SECTION OF "SIGMA'S DIBBLE"—SCALE, ¼ OF FULL SIZE.

chambers *b*, apertures or channels *c* run obliquely up to the bottom of the seed-chamber *a*. Stretching from end to end of the seed-box, a flat bar *d d*, fig. 359, is placed, the ends of this passing out through apertures in the ends of the seed-chamber *a a*, and its flat side lying in close contact with the floor or bottom of the chamber. On the supposition that this flat bar was solid from end to end, it would completely cover the holes in the floor of the seed-chamber, and stop all communication with the oblique channels *c* leading to the vertical chambers *b*, fig. 360. But in the bar *d d*, fig. 359, apertures corresponding in diameter to that of the chamber *c* are bored at intervals equal to those of the vertical chambers *b*, fig. 360. When the solid parts of the flat bar *d d*, fig. 359, are opposite the apertures of the oblique channels *c*, communication is closed, but on moving the flat bar laterally till the holes in it coincide with the apertures of the oblique channels, the communication is made between the seed-chamber *a* and the vertical chambers *b*. In these vertical chambers five steel dibbles *e e e*, figs. 359 and 360, move up and down, these being fixed to the cross-bar *f f*, running parallel with the top of the seed-box. This cross-bar *f f* has two standards *g g*, supporting at its upper extremity the handle *h h*. By lifting up and depressing the handle *h h*, the cross-bar *f f* and dibbles *e e e* are alternately moved up and down in the vertical chambers *b*. The amount of rise and fall or play of the dibbles *e e e* in the vertical chambers is such, that when the handle *h h* is pulled up to its full extent, the lower end of the dibbles is clear of the lower apertures of the oblique channels *c*.

1039. It remains only for us to describe how the flat bar *d d*, fig. 359, is moved laterally, so as to open the holes *c* in the bottom of the seed-box simultaneously with the rise of the dibbles *e e* in the vertical chambers *b*. Near the centre of the seed-box, and on a stud fixed on its side, a curved lever *i k*, fig. 359, vibrates. The long curved arm *i* of this lever passes through a slot *l* in the bar *f f*, which carries the dibbles *e e e*, the slot being long enough to admit of the lateral movement of the arm *i*. In the slot two circular studs *m m* are fixed, the end *i* of the lever *i k* passing between them. If the long arm *i* was straight, it would work up and down between the studs without any movement on the bar *f f* being raised and depressed, but as it is curved, the studs *m m* follow the line of curve, tending to push the arm *i* laterally; and as *i* vibrates on a centre, the other or lower arm *k* has a corresponding lateral movement, but in the contrary direction. The extremity of the lower arm *k* rests on a lateral slot made in the flat bar *d*, so that when the arm *k* moves from side to side, it moves also the flat bar *d d*. Brushes *n n* are placed so as to brush the upper side of the bar *d d*, thus tending to keep the aperture free from all adhering matter. The handle by which the apparatus is lifted is connected with the seed-box, the two standards *o o* supporting the cross-handle *p p*. In fig. 360 *r* is a step or foot-plate for depressing the apparatus into the earth.

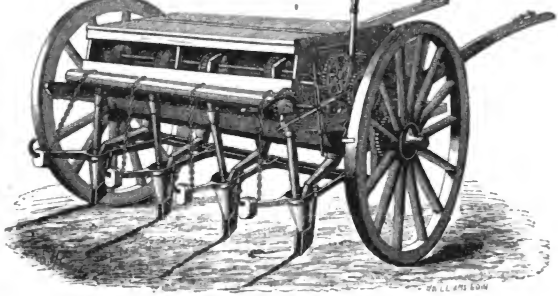
1040. The price of a five-row apparatus, to deposit five grains in each hole, is £3, 3s.

1041. *Liquid and Solid Manure Distributors.*—We now come to describe useful forms of liquid-manure drills and carts, and solid-manure distributors.

1042. *Chandler's Liquid-Manure Drill.*—In Plate XVIII. we give two views of a well-known form of liquid-manure drill, the invention of Mr Chandler, and which is manufactured by Messrs Reeves of Bratton, Westbury, Wilts. Fig. 1 is a side, and fig. 2 an end elevation, both drawn to a scale as given in the Plate. In fig. 361 we give a perspective view of the drill as used without the drop apparatus figured in the Plate; and in fig. 362 we give on a larger scale, 1 inch to the foot, a front section of the upper part of fig. 1, Plate XVIII., showing the buckets for lifting the liquid manure into the delivery-tins.

1043. In figs. 1 and 2, Plate XVIII., *h h* are the driving-wheels, 4 feet in diameter, *i i* the frame, 3 inches by 2½, supporting the manure-box *j j j* and seed-box *k*, and the working gearing. The total depth of manure-box *j* is 2 feet 7 inches, its length 2 feet 5 inches, and its greatest breadth 2 feet 8 inches. On the axle of the driving-wheels *h h*, a spur-wheel *l*, 12¼ inches diameter, is keyed, engaging with a spur-wheel *m m*, 12 inches diameter. This is keyed on the shaft of the bucket-barrel *a a a*, fig. 362. The spur-wheel *m m*, fig. 1,

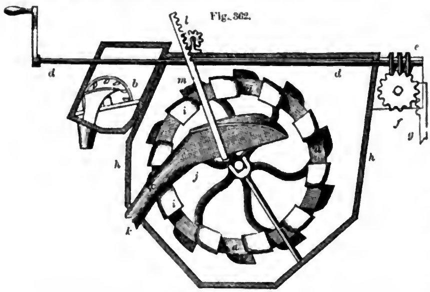
Fig. 361.



PERSPECTIVE VIEW OF CHANDLER'S LIQUID-MANURE DRILL.

Plate XVIII., engages with an intermediate wheel *n n*, 15 inches diameter, this engaging with the wheel *o o*, 10 inches diameter. This wheel *o o* is keyed on, and gives motion to the shaft of the seed-cup barrel *b*, fig. 362. The seed is delivered to the delivery-cans *g g*, fig. 2, Plate XVIII. The liquid manure passes down the tubes *q q*, *q q*, and the united seed and liquid pass finally to the drop apparatus *d*, fig. 1, through the delivery-tins *r*.

Fig. 362.



SECTION OF SEED AND MANURE CHAMBER OF CHANDLER'S LIQUID-MANURE DRILL. —SCALE, 1 INCH TO THE FOOT.

1044. The coulter-levers, as *b b*, fig. 1, are lifted up by the chain *s s* passing over the chain-barrel *t t*, 4 inches diameter and 3 feet 6 inches long. The barrel is worked by the cross *u u*, which is fixed to the shaft. The manure and seed-box are adjusted on going up or down hill by the lever *c*, keyed on the shaft or spindle *d d*, fig. 362, to the extremity of which a worm-screw *e* is attached, this engaging with the worm-wheel *f*, the teeth of which take into the rack of the lever *g*. In fig. 1, Plate XVIII., *v* is the lever; *w* the shaft; *x* the box containing the worm-wheel and screw *e*, *f*; *y* the lever of the rack *g*, of fig. 362.

1045. In fig. 362, *a a* is the bucket-barrel, 1 foot 10½ inches in diameter, the shaft of which revolves in the bearings as shown. Buckets 3½ inches long, and 2¾ inches deep, are attached by bolts and screws to the barrel or cylinder *a a*. The spur-wheel *m m*, fig. 1, Plate XVIII., is keyed on to the shaft of the barrel *a*, fig. 362, and as it revolves amidst the liquid manure which fills the manure-box *h h*, the buckets *i i* deliver it to the spout *j*, from which it passes off to the delivery-pipe *k*, and finally to the delivery-tins *r r*, *r r*, fig. 2, Plate XVIII. When the liquid manure is not wished to be passed to the spout *j*, and pipe *k*, fig. 362, and delivery-tins *r r*, the spout *j* is lifted up—being jointed at *o*—by the link *m*, the upper end of which has a rack which is worked by the wheel *l* (*z* in fig. 1, Plate XVIII.) This wheel *l*, fig. 362, is keyed on to the shaft, 1 1, fig. 2, Plate XVIII., worked by the hand-lever 2.

1046. The price of Chandler's liquid-manure and drop drill varies from £22 to £28.

1047. *The Water-Cart.*—The cart has been very long in use for the conveyance of water, when the supply of that necessary element for household use has been distant from the steading; and the liquid-manure cart is its offspring, modified by certain additions, to adapt it to this change of purpose. The water-cart is usually the naked bed-frame of a cart, mounted on wheels, and surmounted with a cask of a capacity suited to the demands of the establishment. The cask is furnished with a funnel, inserted in or attached immediately over the bung-hole; and it is likewise furnished with a spigot, or with a stop-cock, inserted into that end of the cask which hangs over the back of the cart. When the water-cart has been drawn to the fountain or the pond, from which water is to be conveyed, it is filled either by means of a common pump, raised so high as to deliver the water which it lifts into the funnel of the cask, or the water is lifted with the hand by means of a *scoop*, having a helve of sufficient length to enable the workman to reach the pond on the one hand and the funnel on the other.

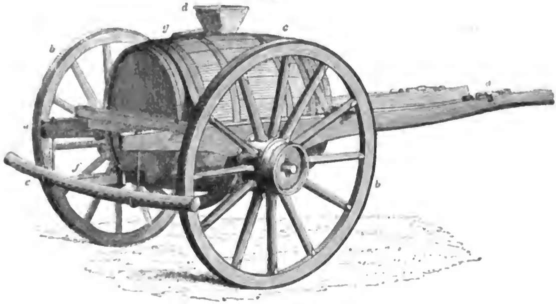
1048. *The Liquid-Manure Cart.*—This, as most commonly used, differs very little from the water-cart, except in its being provided with the distributing apparatus in place of the spigot; but in large establishments the cask is superseded by a covered *rectangular cistern or tank*, which takes the place of a common cart-body.

1049. The *watering* of public streets and highways has induced the necessity of the rectangular tank for the distribution of water over the surface of roads, because of the ease with which, by this construction, a greater quantity of water can be put upon one pair of wheels. Here the quantity of water to a given surface is much greater than in the case of a liquid manure, and hence the propriety of a capacious tank for the distribution of *water* on streets, while the same principle (economy in the expense) leads to the propriety of employing a smaller and less expensive vessel for the distribution of liquid manure, which will not in general be superabundant.

1050. For a *liquid-manure cart*, a cask of 120 or 140 gallons contents will be found more economical in first cost than a rectangular tank; and as these machines can be only occasionally in operation, they will, if not very carefully attended to, become leaky while standing unoccupied. In this respect the cask will have a manifest advantage over the tank, for the tightening of a cask is an operation the most simple, by the act of driving up the hoops; while, in the case of the tank becoming leaky, no means of that kind can be resorted to, and the alternative is, either soaking it in water till the wood has imbibed as much of the fluid as will expand its substance and close the leaks, or the vessel must be tightened by some more expensive process. As the more economical of the two, therefore, in point of expense, we have chosen the cask-mounted cart for the illustration.

1051. Fig. 363 is a representation in perspective of this cart, of the simplest and most convenient construction. For the more easy means of filling the cask, it is suspended between the shafts of the cart, and this position requires the bending of the axle to nearly a semicircle. The cart is a mere skeleton, consisting of the shafts *a a*, which for this purpose may be made of red pine, their length being about 14 feet. They are connected by a fore and hind

Fig. 368.

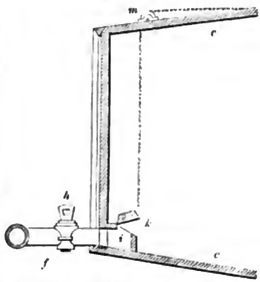


THE LIQUID-MANURE CART

bar, placed at such distance as will just admit the length of the cask, while the width between the shafts is suited to the diameter of it. The axle, as already noticed, is bent downward to nearly a semicircle, to receive the cask, and its length will, of course, be greater than the common cart-axle; even the distance between the caddy-bolts, in a straight line, will be usually greater, but this will depend on the diameter of the cask. A pair of common broad cart-wheels *b b* are fitted to the axle. The cask *c* is suspended on two straps of hoop-iron, 2 inches broad, the ends of which are bolted to the shafts, and the same bolts pass also through the ends of two lighter straps which pass *over*, and secure the cask firmly in its place. The funnel or hopper *d* is usually fixed upon the top of the cask over the bung-hole, or it may be inserted therein by means of an attached pipe.

1052. The distributor *e* may be made of sheet-copper, of cast-iron or malleable iron, or even of wood; the copper will be found the most durable, and it should be at least $\frac{1}{20}$ of an inch in thickness. The next best is the patent malleable-iron tube; cast-iron, though sometimes used, is not to be recommended, neither is wood desirable, from its liability to choke. The bore of the distributor should be not less than 2 inches, nor is it required to exceed $2\frac{1}{2}$ inches, the length from 7 to $7\frac{1}{2}$ feet, and slightly bent with a uniform curvature, which last property causes it to cover a wider surface of ground than it would do if straight. But in giving the distributor its curvature, care must be taken to avoid increasing the curvature towards the ends, as is sometimes done, to the prevention of uniform distribution of the manure. The ends of the tube must be closed with movable covers, screwed or otherwise fixed, that they may be removed at pleasure, for the purpose of sponging out the tube when it happens to get clogged up with any solid matter. A line of perforations is made along the hinder side of the tube for the discharge of the fluid: these should be at the distance of 1 inch apart, and their opening about $\frac{1}{8}$ inch diameter. As the area of these discharging orifices cannot be altered at pleasure, nor their amount of discharge altered for any given time, it becomes necessary, in distributing any given quantity per acre, to regulate that quantity by increasing or diminishing the *rate* of travelling the cart over the ground. The distributor is attached to the cask by means of a stem *f*, of the same materials and bore as the main tube, and it enters the end of the cask close to the lower chime. A stop-cock is frequently put upon the stem *f* to regulate the discharge, and for this purpose it is very beneficial, serving in a great measure to regulate the quantity per acre; but for the entire setting off or on of the supply, the stem *f* opens into a small chamber inside the cask, which chamber is closed by a flap-valve heavily loaded. This valve when closed stops the discharge, and when lifted the fluid has a free passage to the distributor. The opening of the valve is effected by a small chain attached to the flap, rising to the top of the cask at *g*, where it passes over a small roller, and onward to the fore part of the cart on the nigh side, where it hangs at hand for the carter to set off or on at pleasure.

Fig. 364.



THE APPARATUS FOR REGULATING THE DISCHARGE FROM THE LIQUID-MANURE CART.

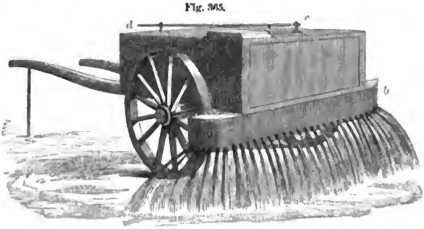
1053. Fig. 364 is a section of part of the cask, and showing the chamber and valve; *f* is again the stem of the distributor, *h* a stop-cock, *i* the chamber, and *k* the valve, which is the common leather flap or clack-valve well loaded with lead; *c c* is part of the cask, *l* the chain attached to the valve and passing over the roller *m*.

1054. When the liquid-manure cart is furnished with a *tank*, the latter can, with equal facility, be placed low for the convenience of filling; thus the axle may be cranked, as in the Liverpool dray-cart, the tank resting on the cranked part of the axle; or the axle may remain straight, and the tank appended below the axle. Such a tank may be conveniently built to contain a ton of the liquid, or about 220 gallons; and the distributing apparatus is the same as for the cask.

1055. The price of these liquid-manure carts varies considerably, partly from construction, and partly from locality. Mr Crosskill, of Beverley, quotes £25 as the price of the tank-cart. In Scotland the average price may be stated at £18, and when mounted with a cask, £15; these prices, of course, including wheels and axle.

1056. *James's Liquid-Manure Cart.*—In fig. 365 we illustrate a liquid-manure cart which enjoys a high reputation in England. It is invented and manufactured by Mr Isaac James, of Tivoli Iron Works, Cheltenham. In this form of liquid-manure cart the principal peculiarity is the adoption of two strainers at *a*, through which the liquid is passed before it enters the body of the cart, arresting all extraneous matter tending to choke up the holes in the distributing-box *b b*. The liquid is discharged from the body of the tank *a* to the distributing-box through a conical valve fitted to the lower extremity of the rod *c*, and which is actuated by the lever handle *d*. All the joints are waterproof.

Fig. 365.



JAMES'S LIQUID-MANURE CART.

1057. Price of James's liquid-manure cart, to hold 250 gallons, to be worked by horse, is £24—the weight of cart when empty being 8 cwt., when full, 29 cwt. The price of a cart to be worked by a boy, holding 10 gallons, and weighing when empty 2 cwt., and when full 6 cwt., is £10.

1058. *Solid Manure Distributors.*—The experience of every succeeding day tends to show the extension of the application of granulated manures to the soil; and the powerful influence of some of them, coupled with the high price of the article, renders the necessity of a uniform and sparing distribution of them imperative. Machines being better adapted to the performance of a uniform distribution than a number of individual hands, and as they can likewise be adjusted to deposit either a larger or smaller quantity with uniformity, the demand for such machines must increase with the extending application of the manures.

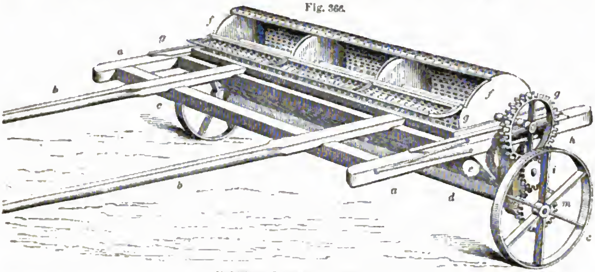
1059. It is found, however, that any one form of machine is not fitted to deposit all the varieties of such manures, and that to some extent each kind has required its own peculiar construction of the distributing parts of the machine. The late introduction of guano has increased this difficulty; for in the more early application of it, the article was purchased always in a very damp state, and care was taken to impress on the mind of the purchaser that a state of natural dampness was requisite to retain the virtues of the manure until it was put into the soil. This circumstance caused much trouble to those who attempted to distribute the manure with machines, for by reason of its dampness, aided by the action of the revolving parts of the machines, the guano was converted into a paste, and the machine ceased to perform its wonted duties. But it soon became evident that the dampness so much recommended by the vendor was only the effect of a liberal administration of water applied by him to increase the weight of the article, and the amount of his own profits; and this detection once made, we now see the article publicly recommended for its dryness. The previous state had, in the mean time, called forth a degree of attention to the means of distributing that and other roughly granulated substances through the machine usually employed, and this has extended our knowledge in this department of agricultural machine-making.

1060. The results of these inquiries and experiments have been to produce a conviction, that the simple principle of distribution so successfully employed in the broadcast and grain drill sowing-machines, Plates XIII. and XIV., may, with very slight modification, adapted to the particular object, be rendered available for almost all granulated manures, more especially now that the important article of guano will generally be procurable in a dry state, which hitherto has been the most difficult to accomplish.

1061. Soot, as a manure, has presented the same difficulty in its distribution from the ordinary machines; and as an example for both of these articles, it may be stated that a machine, such as seen in Plate XVI., fig. 1, which is adapted for bone-dust, will neither deliver guano nor soot in a regular manner. Hence, also, the following machine, constructed for the distribution of soot as a top-dressing, has been greatly improved by the application to it of the principle of the broadcast sowing-machine.

1062. *Main's Soot-Sowing Machine.*—From the limited supply of soot which it operates upon, this machine can never be ranked amongst the most important class of machines on the farm; still, owing to the powerful effect of the manure itself, its due distribution is of importance, and, from its extreme lightness, it cannot, without disadvantage, be sown by the hand. The machine here described was the production of Mr Main, factor to the Earl of Dalhousie.* Fig. 366 is a view in perspective, the horse-shafts being broken off; and fig. 367 a trans-

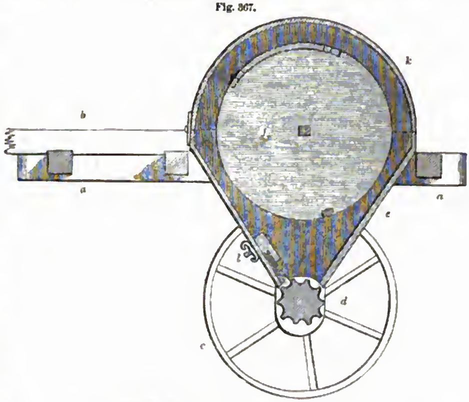
Fig. 366.



MAIN'S SOOT-SOWING MACHINE.

verse section, with the shafts also broken off, the letters of reference applying to corresponding parts in the two figures. The machine consists of a bed-frame *a a*, to which the horse-shafts *b b* are attached, and is mounted on a pair of low wheels *c c*, of 22 inches diameter, fixed upon, and turning with, the axle, around which there is built a wooden cylinder *d*, about 6 inches diameter and 6 feet in length, fluted longitudinally. A chest *e*, 6 feet in length, is appended to the body-frame, and descends so far as to half embrace the cylinder *d*, and is surmounted by a semi-cylindrical cover, which is left out in fig. 366, but is seen in section *k*, fig. 367. In the interior of the chest there is placed a cylinder of sheet-iron *f*, 22 inches in diameter, perforated all over with holes of ½ inch diameter, and as much apart, giving to it the character of a riddle. The cylinder is closed at both ends, and has a trap-door on one side, as seen in fig. 366, hinged, and secured at each end with hook and eye. An axle of iron passes quite through the cylinder, having journals that rest in two jointed bars *g g*, *g*; and on one end of the axle, produced beyond the bar *g g*, is mounted a wheel *h*, of 18 inches diameter. The axle of the carriage-wheels *c* carries also a wheel *m* 9 inches diameter, and the two are connected by means of the

Fig. 367.



TRANSVERSE SECTION OF MAIN'S SOOT-SOWING MACHINE.

* *Prize Essays of the Highland and Agricultural Society*, vol. xii. p. 535.

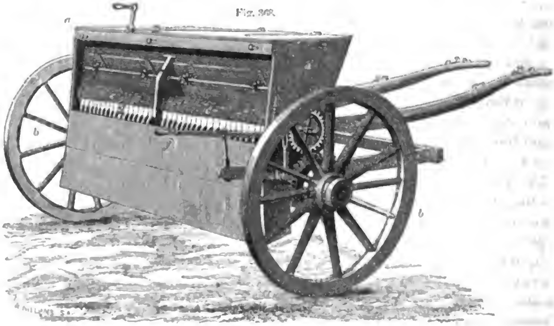
intermediate wheel *i*, thus producing motion in the perforated cylinder, as well as in the fluted one that is carried by the axle. The purpose of the perforated cylinder into which the soot is first delivered, is to separate stones or other hard substances that may be mixed with it; that of the fluted cylinder being the distribution of it from the machine; and the hinged cover prevents it flying off during the agitation by the first cylinder.

1063. The operations of the soot-machine are effected thus:—A charge of soot is put into the cylinder, the chest closed, and the machine put in motion. By the revolution of the upper cylinders, the soot is separated from the stones and refuse with which it is always mixed, and so passes into the lower part of the chest, from whence, by the revolution of the fluted cylinder, regulated by a brush *l* extending the whole length of the cylinder, it is distributed in an equal manner upon the ground. When the soot has been discharged from the upper cylinder, the cylinder is raised from the chest by means of the knee-jointed bars *g g*, and when so elevated, the trap-door is opened, and the stones and other refuse discharged, preparatory to the next charge of soot.

1064. The machine, constructed as above described, has been found liable to the inconvenience before pointed out in par. 1061, but which has been effectually rectified by the adoption of the broadcast distributing-wheels, in place of the fluted roller; the bottom of the chest is consequently closed, except the orifice for each wheel, all the other parts of the machine remaining as they were; or by a proper adjustment, the intermediate wheel *i* is left out of the construction. It is also to be observed, that the distributing orifices for the soot require to be about 1½ inch diameter.

1065. *Chambers's Broadcast Manure-Distributor.*—A most efficient broadcast manure-distributor, calculated to sow all kinds of manure, is that invented by Mr Chambers of Fakenham, and manufactured by Messrs Garrett. Of this, in Plate XIX., we give fig. 1, a back or end, and fig. 2 a side elevation, and fig. 3 a transverse section of part of the machine on a larger scale; fig. 368 is a perspective view. The scale to which figs. 1 and 2 are drawn is ½ inch to the foot; fig. 3 is ⅛ of the full size.

Fig. 368.



CHAMBERS'S BROADCAST MANURE-DISTRIBUTOR IN PERSPECTIVE

1066. The box *a a*, fig. 1, Plate XIX., 6 feet 6 inches long, containing the manure, is carried by the wheels *b b*, 3 feet 7 inches diameter. A nave-wheel *c*, 12 inches diameter, engages with and gives motion to the spur-wheel *d*, of same diameter. This is keyed on the shaft of the revolving manure-barrel *e e*.

This is composed of short cylinders or pulleys, 5 inches in diameter, fixed on the central shaft, with discs of thin metal placed between them. These short cylinders consist of a flat disc of metal, having a box or square hole in the centre, through which is passed the central shaft. The periphery of each cylinder *a a*, fig. 3, is furnished with projections *b b*. The cylinders, as they revolve, are scraped clean by the extremities *c*, of the scrapers *d*, oscillating or vibrating in the centre *e*. The pressure of the points *c* in the cylinders is regulated by the weights *f*, these being placed nearer to or further from the centre *e*, in the notches on the upper side of the lever *d d*. The assemblage of weights is shown at *f f f* in fig. 1.

1067. As the manure passes from the manure-box—which is divided by partitions *g g*, fig. 3, into four compartments, to equalise the delivery on hill-sides—it is subjected to the reciprocating stirrers *g g*, fig. 1, and *h*, fig. 3. Motion is given to the shaft on which these stirrers are fixed through the medium of the crank *d*, fig. 2, the shaft of which receives motion from the bevel-wheels *h*, fig. 1, and *c*, fig. 2, *c* being keyed on the shaft of the manure-barrel *e e*, fig. 1. From the scrapers *g g*, fig. 1, the manure is then carried over the manure-cylinder *e e* (*a a*, fig. 3), where it is further subjected to the action of the projections *b b*, and the scrapers *c*, fig. 3. It falls from thence into the trough *f*, fig. 2 (shown in dotted lines in fig. 1), and is sifted by the wire-rods *g*, from whence it is delivered evenly on the surface of the land.

1068. The quantity of manure delivered is regulated by the lever *h h*, and spring *i*, fig. 2, which works the rack and pinion *i j*, fig. 3, the rack forming part of the slide *g*. The wheel *d*, fig. 1, is thrown in and out of gear with the nave-wheel *c*, by means of the lever *j*, fig. 2, and fig. 368. The position of the manure-box *e* is adjusted by the winch-handle *k* (fig. 368), and face-wheels *l*, acting on the rod *m*, fig. 2.

1069. The price of Chambers's broadcast manure-distributor is £21.*

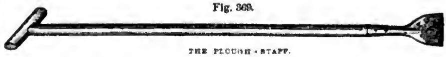
1070. SECTION SIXTH.—*Manual Implements connected with the Cultivation of the Soil.*—This section comprehends all the manual implements—or perhaps it would be better to term them the *hand* implements—employed on the farm in the cultivation of the soil. They are appropriately named *hand* implements, because they are used by the hands of the labourers to do the work these have to do with them in a direct manner and with individual skill; whereas, in regard to machines actuated by power, labourers have only to superintend, and it may be to guide their operations. Those parts of machines moved by power, which are acted on by the hand, might also perhaps be strictly called *hand* implements; but there is this distinction to be observed between the two cases, that the labourers have no direct control over the work performed by such machines, nor can they show their individual skill by their means. The hand implements comprehended in this section co-operate with the machines described in the preceding five sections on the cultivation of the soil, and might therefore have been placed and described in their respective sections. But it has been deemed most convenient to place them by themselves in a separate section, in order to show their number and simplicity of form in the most obvious manner, rather than permit them to interfere, by their presence, with the necessarily elaborate descriptions of the more complicated machines. The hand implements which follow, are given in the order of the subjects contained in the preceding five sections.

1071. *The Plough-Staff.*—Fig. 369 represents the plough-staff—a necessary article of the movable furniture of the plough. It is in form of a small

* In paragraph 1037, for *described in fig.* 357, read *figs.* 1 *and* 2, *Plate XVIII.*

shovel, having a socket into which a helve 5 feet in length is inserted, and in some parts of the country this is furnished with an oblique cross-head. Its

Fig. 369.

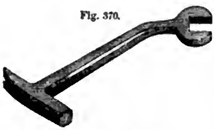


THE PLOUGH-STAFF.

position in the plough is to lie between the handles, and its use to enable the ploughman to remove all extraneous matter, as earth, that may adhere to the mould-board, or stubble, roots, weeds, that may accumulate before the coulter. It is common to all ploughs.

1072. *The Iron Hammer Nut-key.*—Every plough should be provided with a very useful appendage, an iron hammer, fig. 370. The head and handle are forged in one piece of malleable iron, the handle being formed into a nut-key. With this simple but useful tool, the ploughman has always at hand the means by which he can, without loss of time, alter and adjust the position of his plough-irons—the coulter and share—and perform other little operations which circumstances or accident may require, for the performance of which most ploughmen are under the necessity of taking advantage of the first *stone* they can find, merely from the want of this simple instrument. The hammer is slung in a staple fixed in the side of the beam in any convenient position upon the left-hand stilt. This little appendage is confidently recommended to all ploughmen, as an essential part of the furniture of the plough.

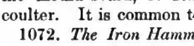
Fig. 370.



THE IRON HAMMER NUT-KEY.

1073. *Plough-Slide.*—In removing ploughs from one field to another, or along a hard road to a field, instead of sliding them upon their sole-shoe, which is difficult to do when it has no hold of the ground, or upon the edge of the feather of the sock and the side of the mould-board—which is a more easy mode for the ploughman than on the sole-shoe, and is consequently more commonly taken—every ploughman should be provided with a plough-slide, a simple and not costly implement, as represented in fig. 371. It consists of a piece of hardwood board 3 feet 4 inches long, 8 inches broad, and 2 inches thick, in which a long staple *a* is driven to take in the point of the sock; and at *b* are fastened two small bars of wood, longways, and at such distance from one another as to take between them the heel of the sole-shoe of the plough. On the under side of the board is nailed two pieces of flat bar-iron, to act as skeds to the slide. Upon this implement the plough may be conveyed with comparative ease along any road or head-ridge.

Fig. 371.



THE PLOUGH-SLIDE.

1074. *Feering-Poles.*—Feering-poles are a number of round bars of wood 8½ feet in length and 1½ inch diameter, graduated into feet and half feet. Each pole is painted at the top of a different colour, and of a marked colour from ordinary surrounding objects. Feering-poles are used for setting off the breadths of ridges and of cross-ploughings.

Fig. 372.

FEERING POLE.

1075. *Plough Harness.*—In Plate VI., fig. 2 is a representation of a plough drawn with two horses in harness. The harness, which in its separate parts constitutes the implements by which the horses draw the plough, consists of the following particulars, each of which is simple in the extreme:—(1.) The *collar* around the horse's neck, to serve as a padding to protect his shoulders from being injured by the draught. It is stuffed with wheat-straw, faced with neat's leather, and lined with rug cloth, and provided with a cape to fend the rain off from the shoulders of the horse, which would thereby be heated and blistered in the draught. The collar weighs about 15 lb., and costs £1. (2.) Embracing a groove in the anterior part of the collar are the *haims* or *hames*, composed commonly of two pieces of wood curved towards their lower extremities, where they are attached together by means of a hook and short chain; and their upper extremities are held tight by means of a leather strap and buckle. The haims are provided on each side with an iron hook, to which the draught-chains are linked. When covered with plate-iron, haims weigh 7 lb., and cost 5s. 6d. (3.) Light chains, called *trace-chains*, are fastened at one end to the hooks of the haims in the collar, and at the other to the swing-trees of the plough, for enabling the horses to draw the plough: they weigh 8 lb., and cost 7d. per lb. (4.) The chains are prevented falling down in the middle by the *back-band*, a broad strap of leather which passes over the horse's back, and is padded over the chine: it weighs about 3½ lb., and costs 8s. (5.) The *bridle* is on the horse's head, and has blinders: the *bit* is most conveniently removed by means of a small strap and buckle at one of its ends: the bridle, of good leather, weighs 4½ lb., and costs 10s. (6.) It will be observed in Plate VI., fig. 2, that the ploughman guides the horses by means of *plough-reins*, made of rein-rope, which pass from the stilts of the plough to the bridle-ring of each horse, threading on their way a staple on the back-band. (7.) The horses' heads are kept most steadily by means of a *short rein* of rope from the bridle-ring to the trace-chain of each horse.

1076. *The Common Spade.*—The plough, in its effects upon the soil, is the nearest approach of any implement to that of the No. 5 common spade, fig. 373. With its flat rectangular iron blade and wooden helve fastened with riveted nails into the split socket attached to the blade, the common spade is too well known and too commonly in use to require any description of its construction. To the gardener, who turns over the surface-soil, the spade is indispensable; and to the cultivator of the soil, who improves his land by trenching, it is an efficient implement. In trenching ground with the spade the surface-soil is turned over one spit deep of the blade, and another spit of the same depth is brought up of the subsoil, and put upon the top of the first, making the trenched soil 16 inches deep.

1077. *Parkes' Patent Spade.*—The blade of Parkes' patent spade, fig. 374, is of steel, and the lower part of the helve attached to the blade is of tubular iron, the handle and the upper part of the helve being of wood. This is a very light and clever implement for turning over the surface-soil, and in smooth ground would last many years, but on rough stony subsoils it could not undergo the fatigue of the common spade.

1078. *The Ditcher's Shovel.*—The ditcher's shovel, fig. 375, is 1 foot broad and 1 foot long, tapering to a point, with a helve 28 inches in length, furnished with a short cross-handle, and costs, No. 5, 4s. Its uses are to clear the sides and bottoms of ditches of loose earth, to clear the bottom of a trench of loose earth and stones, and to clean up the bottoms of dunghills on soft ground, which it does better than any broad-mouthed shovel.

Fig. 373.

THE COMMON SPADE.

Fig. 374.

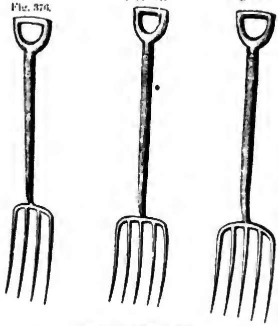
PARKES' PATENT SPADE.

Fig. 375.

A DITCHER'S SHOVEL.

1079. *Parkes' Digging Forks.*—The common spade, on turning over the surface-soil in spits, preserves the earth in lumps; and when the soil is tenacious, those lumps may be difficult to pulverise. It was deemed reasonable, that if, instead of using a blade, an implement were employed to turn over the soil, having a number of prongs pretty closely set together, the earth would be broken and even comminuted in the act of being turned over. Accordingly, such forks as are represented by figs. 376, 377, and 378, were contrived by Mr Parkes for that purpose, and they have been found to answer. They are made of steel prongs, four and five in number, more or less closely set together, and having tubular-iron helves attached to them like his steel spade, fig. 374, with a handle and upper part of the helve of the wood.

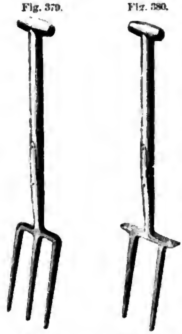
Fig. 376. Fig. 377. Fig. 378.



PARKES' DIGGING-FORKS

1080. *Trenching-Forks.*—In trenching ground, it may be desirable to keep the subsoil at the bottom, and not bring it up to the surface. The trenching-forks, such as in figs. 379 and 380, afford ready means of accomplishing that object. After the surface-soil has been removed from the trench by the common spade, fig. 373, the trench-forks are then used. When the subsoil is not very hard, and not many stones in it, the fork of three prongs, fig. 379, is used to loosen the subsoil to the depth of the prongs, and to let it remain in the loose state where it is. When the subsoil is hard, and the stones many, the two-pronged fork, fig. 380, is better suited to loosen the subsoil and cast out the stones than the three-pronged. Fig. 380 is provided with tramps for the foot to press upon, and force the prongs into hard ground. The prongs, two or three in number, are 15 inches in length and 1½ inch in depth at the neck, tapering to a stout point. The prongs are connected with a hose, into which an ash helve with a short cross-handle is fastened. The entire fork stands 3 feet 9 inches in height, and costs 5s.

Fig. 379. Fig. 380.



THE TRENCHING-FORKS WITH THREE AND TWO PRONGS.

1081. *The Hand-Pick.*—When the subsoil is so hard that the two-pronged trenching-fork, fig. 380, cannot easily be made to penetrate, then the hand-pick, fig. 381, is used to loosen both the subsoil and the stones. The points of the hand-pick are sharp, and the handle, acting as a lever, gives the labourer a considerable power in overcoming the adhesive property of the subsoil and the tenacious hold of the boulder-stone. In soft adhesive clay the hand-pick is of little use, only picking out as much of the earth as the breadth of the pointed end of the pick. The pick is made of a bar of iron brought to a point at each end, and curved to a segment of a circle. The handle is 3 feet in length, is of ash fastened by wedges in a swelled eye, spreading upwards, forged in the middle of the bar of iron. Each arm is 18 inches long by 2½ inches deep and 1¼ inch broad, and the cost of the implement is 5s. 6d. or 6s.

1082. *The Foot-Pick.*—The hand-pick is severe upon the arms of the labourer when using it in hard ground containing many imbedded small stones. The foot-pick, fig. 382, in such a case, is an easier implement for him: it stands 3 feet 9 inches in height. The shank is of iron, ¾ inch square at the neck under the eye, through which the cross handle passes, and it is 1½ inch broad at the tramp. The tramp is movable, and may be shifted to either side of the shank to suit the working-foot of the labourer, and it remains firm at 16 inches from the point, which inclines a little forward to assist the lever power of the implement in loosening hard soil or in removing large stones. The cost is 6s. 6d. It is used in this manner:

Fig. 381.

THE HAND-PICK

Fig. 382.

THE FOOT-PICK.

The labourer raises it by the handle with both his hands, with the point bending away from him, and thrusts the point with force into the ground, and works the pick down with the pressure of his foot upon the tramp, until the implement has penetrated as far as the tramp, which is 16 inches. He then pulls the handle towards him, and the shank, acting as a lever upon the surface of the ground as a fulcrum, the point raises the ground before it in a mass, or displaces any stone that may be in its way. Should the ground be too hard to yield entirely to the power of the man's arms alone, he increases his power by sitting upon the handle, and pressing with successive impulses against it with the weight of his body.

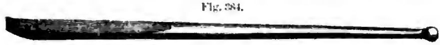
1083. *The Mattock.*—In trenching ground, roots of trees or bushes may sometimes be met with. No implement is so efficient in cutting the ramified roots of trees or bushes as the common mattock, fig. 283, which has arms and helve of the same dimensions as those of the hand-pick, fig. 381, described above; but, instead of being pointed, one arm has a horizontal and the other a vertical cutting-face of 3 inches in length.

Fig. 383.

THE MATTOCK

1084. *Iron Crow-Bar.*—In improving waste land, large stones are frequently found imbedded in the soil, which the ploughs, whether trenching or subsoiling, cannot remove from their places. The stones which cannot easily be displaced with the hand-pick, fig. 381, or even with the foot-pick, fig. 382, may be so with the iron crow-bar, fig. 384. It is simply a strong round bar of iron, 6 feet in length, tapering gradually from the lower end, which is flattened and a little turned up to give a firmer grip of the stone, to the upper end, which is most commonly finished with a small knob. The crow-bar acts simply as a lever of the first order, requiring a hard stone conveniently placed for a fulcrum.

Fig. 384.



IRON CROW-BAR.

1085. *Stone-Slide.*—The large stones which require the iron crow-bar, fig. 384, to displace out of their position, are most easily taken out of the field by means of a slide, fig. 385. It is made of two pieces of wood, at least 6 inches square, *a a*, fastened together at one end at an angle by plates of iron secured with bolts and nuts, and the other ends are connected by a 4-inch square bar *b*, fastened with bolt and nut. A piece of a tree naturally branched, as *a* and *a* are represented in fig. 385, is the strongest and most convenient form of slide. A staple with a ringed hook *c*, to attach a swing-tree to, for one horse, is fastened at the apex of the slide. Fig. 385 shows the implement in plan, and fig. 386 in a side elevation, where *a a* is one of the bars, *b* the square connecting-bar, and *c* the draught-hook. The under side of *a a* is shod with iron, such as with the tire of an old cart-wheel, to save the wood from wear. Where the stones are large, two horses may require to be yoked, with double swing-trees, fig. 288, to the draught-hook *c*.

Fig. 385.

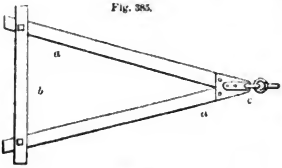
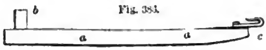


Fig. 386.



STONE-SLIDE.

1086. *Jumper and Quarry-Hammer.* — When the stones are too large to be removed by the slide, fig. 385, they will require either to be buried out of reach in the soil, or broken into convenient pieces by means of gunpowder, for removal by cart or slide. The burying of large stones in deep and capacious holes is too expensive a process to be much practised, but the blasting of stones is attended with little difficulty. For that purpose two instruments are mainly required—a *jumper*, fig. 387, and a quarry-hammer, fig. 388. The jumper consists simply of a rounded bar of iron, flattened at one end to a breadth exceeding the diameter of the bar, and hardened, and at the other into a flat knobbed head. The hammer is of iron, of a rectangular form, with hardened faces, and furnished with a wooden helve. The jumper is used by one man holding it in a perpendicular position, and turning it progressively round as it descends into the hole forming in the stone by the assistance of water, while another man uses the hammer, with a short and firm hold of its helve, in repeated smart strokes upon the top of the jumper. Very large boulders require more than one blast to reduce their parts, so as to be easily removed from the field either by cart or slide.

Fig. 387.

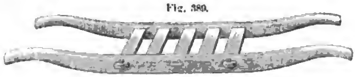
THE JUMPER.

Fig. 388.

THE QUARRY-HAMMER.

1087. *The Hand-Barrow.*—Stones of a size not easily lifted by the hands, and those also which cannot be lifted in the arms, and yet are too small for the slide, fig. 385, are best removed from the field by cart and horse. The easiest way of loading the cart with the largest stones is by means of the hand-barrow, fig. 389, upon which a large stone can easily be canted, and then lifted up by means of the hand-barrow by two or more men into the bottom of the cart. The hand-barrow is of simple construction, sparred, as seen in fig. 389, or boarded.

Fig. 389.



THE HAND-BARROW.

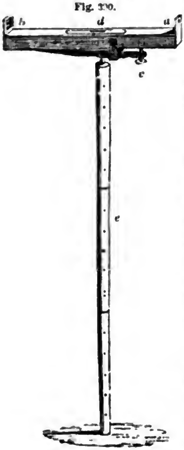
1088. The sides are 5 feet to $5\frac{1}{2}$ feet long, $2\frac{3}{4}$ inches to 3 inches deep by $1\frac{1}{2}$

inch thick in the middle. The five spars connecting the sides are about 2¼ inches by 1¼ inch, all mortised into the sides, the middle spars being cut off flush on the outside, while the end ones project beyond the sides, and are rounded off, a short wooden pin being driven through the projecting ends of the tenons to keep the whole fabric together. All the spars have a small shoulder to bear on each side, the tenon being smaller than the body of the spar.

1089. This is the sparred form of the hand-barrow; another is, that the spars are boarded over, the boards extending to the outer edge of the sides. The sparred hand-barrow answers for lifting large stones. The boarded one is used for carrying any material that would fall through the spars.

1090. *Draining Tools.*—We shall now illustrate the different tools used in draining. Draining is now universally acknowledged to be the great fundamental operation in all improvements tending to a superior cultivation of the soil.

Fig. 390.

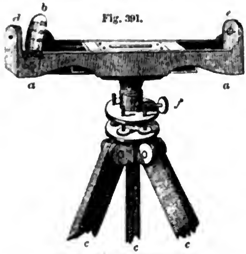


THE SPIRIT-LEVEL.

1091. *The Spirit-Level.*—In setting out drains, and in determining their rate of inclination, a spirit-level is an essential implement. A simple form of this is given in fig. 390. It is furnished with eyesights *a b*, and when in use it is placed in a slight framing of brass, which operates as a spring to adjust it to the level position *d*, by the action of the large-headed brass screw *c*. A stud is affixed to the framing, and pushed firmly into a gimlet-hole on the top of the short rod *e*, the pointed shod end of which is penetrated into the ground at the spot from whence the level is desired to be ascertained. The brass framing is placed between the sights *a b*, with the stud upwards, and a wooden cover put over it, when the instrument is to be carried in the pocket.

1092. *Thompson's Drainage-Level.*—In fig. 391 we illustrate the form of a drainage-level invented and manufactured by Mr H. A. Thompson, Lewes, and which has received the prize of the Royal Agricultural Society, and of the Paris Exhibition in 1856. It consists of a spirit-level in a japanned frame *a a*, with brass graduated arch *b*, and mounted on a tripod-stand *c c c*, with levelling-screws. An iron frame, which carries the two sights *d e*, with cross hairs, is adapted to this. This portion is capable of turning round in a centre, and can be raised or lowered as desired. The apparatus may be used as the ordinary spirit-level illustrated in fig. 390, or by the use of the graduated arch. The rate of rise or fall to any given point may be found by simple inspection. The most favourable fall may also be ascertained by it, by levelling and traversing the instrument in the plane of the horizon. As iron is principally used in its construction, it is very durable. In this level, the adjustment by the parallel plates and screws at *f* is such, that it can sweep round the entire horizon in one parallel plane. The arc *b* is graduated to a percentage scale of 1 in 100, so that when the instrument is adjusted to the level, and the eye-pieces and cross hairs moved vertically till the cross hairs intersect an object the same height as the instrument placed

Fig. 391.



THOMPSON'S DRAINAGE-LEVEL.

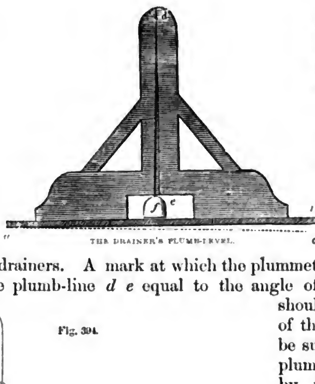
at the outfall, the operator can at once read off, from the graduated arc at the side of the instrument below *b*, the rate of fall. The cost is £1, 18s. with tripod-stand.

1093. *Levelling-Staff for Drains.*—The uniform fall in a drain in sloping ground is easily ascertained by means of three levelling-staffs, fig. 392, with cross-heads 9 inches long, two staffs being about 2 feet in length, and one to suit itself in the drain to the height of the others. One short staff is held perpendicularly on the ground at the upper end of the drain, and another similar one at the lower end. The third staff, adjusted in height to the other two from the bottom of the drain, is gradually moved from one end of the bottom of the drain to the other; the superintendent, placing himself at one end of the drain, and bringing his eye on a line with the upper edges of the cross-heads of the two extreme staffs, observes whether the upper edge of the long staff keeps in the line of the other two. If it does, then the fall of the bottom of the drain is uniform; but where it sinks below the other two, the bottom has been too much scooped out, and must be filled up with earth; and where it rises above them, the bottom is too high, and must be cut down. When the staffs are painted of a contrasting colour, they are most easily distinguished in use.

Fig. 392.

THE LEVELLING-STAFF FOR TESTING THE UNIFORM FALL IN DRAINS.

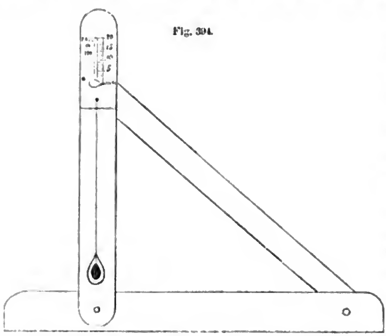
Fig. 393.



THE DRAINER'S PLUMB-LEVEL.

1094. *The Drainer's Plumb-Level.*—As a safe guide in cases where the fall is not decidedly cognisable by the sight, a mason's plumb-level, such as fig. 393, is a convenient instrument for drainers. A mark at which the plummet-line *d f* will subtend an angle with the plumb-line *d e* equal to the angle of the fall of the drain, should be made at the top of the opening *e*, which may be supposed to be where the plummet *f* at present hangs; by which arrangement it is demonstrable that the angle thus set off at *e d f* must always be equal to the angle *b a c*, which is the angle of the inclination of the fall.

Fig. 394.



THOMPSON'S WORKMAN'S BEVEL.

1095. *Thompson's Workman's Bevel.* — In fig. 394 we illustrate Thompson's workman's bevel—an instrument useful in carrying out drains on a uniform slope. This resembles closely fig. 393; indeed, only differs from it in this, that the perpendicular sides can be lengthened or shortened by shifting the hypothenuse, so that it will form any angle with the base which may be desired. The bolt which connects the hypothenuse and the perpendicular, carries an index-head, and works in a slot in the perpendicular. The rate of slope is indicated by the index - point on the graduated scale; and the instrument is maintained at this point by tightening the nut of the index-head. In using the instrument the base is placed in the slope of the drain, and the workman has to see that the plumb-line strikes the centre.

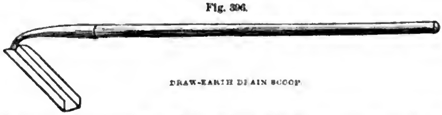
Fig. 395.

THE NARROW DRAIN-SPADE.

1096. *The Narrow Drain-Spade.*—Whatever depth a drain has to be made, it is essentially economical that it be cut as narrow as a man can work in it. After the top of the drain has been removed with the common spade, fig. 373, the narrow spade, fig. 395, follows immediately after it, and being narrow it has a short cross-head on the helve.

1097. *The Draw-Earth Drain-Scoop.*—Should the drain have stood for some days new cut, immediately before the man proceeds to lay the sole-tiles, the wet sludgy matter at the bottom should be removed with the draw-earth drain-scoop, fig. 396. The scoop consists of a trough of iron of the breadth of the bottom of the drain, having a perpendicularly raised edge on each side to retain the sludge. The helve is

Fig. 396.

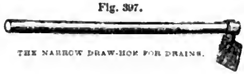


DRAW-EARTH DRAIN SCOOP.

long to reach the bottom of the drain, while the labourer stands across it on the ground, and it is fixed in a socket.

1098. *The Drain Draw-Hoe.*—Where a little dry earth remains at the bottom of the drain, it is most easily removed along with any small stones with a narrow draw-hoe, fig. 397, having a 2-feet helve and a 3-inch-wide blade. Cost, 1s.

Fig. 397.



THE NARROW DRAW-HOE FOR DRAINS.

1099. *The Drain-Trowel.*—To prepare the sole of the drain for bedding the tiles flat, the mason's trowel, illustrated in fig. 398, will be useful. It is 7 inches long in the blade *a*, 5 inches in the handle *c*, and the crank, or return at *b*, 1½ inch in height. In cast-steel it costs 2s.; in common steel, 1s. 3d.

Fig. 398.

THE TROWEL FOR DRAINS.

Fig. 399.

THE NARROWEST DRAIN-SPADE.

1100. *The Narrowest Drain-Spade.*—The lowest part of drains is made much narrower than the upper, to save the expense of digging out an unnecessary quantity of earth. To effect this, the narrowest spade, fig. 399, is an appropriate instrument. It is only 4 inches wide at the mouth, and is provided with a stud in front to press the heel upon when the workman pushes the blade into the subsoil. It serves to throw out the earth loosened by the last picking, and to trim the sides of the bottom of the drain.

1101. *The Pushing Drain-Scoop.*—The loose earth at the bottom of a drain, left by the spades, is best removed when dry with a pushing-scoop, fig. 400.

This scoop finishes the bottom of a drain neatly. Its mouth is a semicircle of iron, to which is attached a socket, in which the long helve is fixed. The

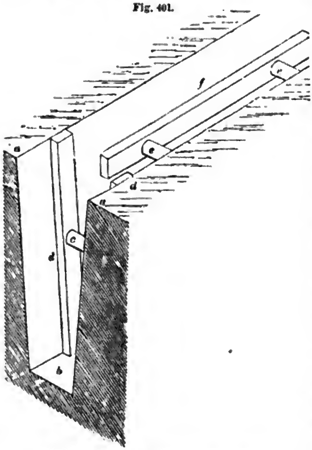
Fig. 400.

THE PUSHING DRAIN-SCOOP.

labourer pushes it from him along the bottom of the drain, while he stands across it on the ground.

1102. *The Planking of Drains.*—The drain required to convey away the contents of a copious and deep spring, and of the waters of a lake, may have to be dug to the depth of from 6 to 10 or 15 feet, according to the lowest depth of the seat of the water to be removed. Should the drain prove very wet, and danger be apprehended of the sides falling in, the whole division engaged in for the time is taken out to the bottom without stopping, in order to let the conduit be built into the drain as quickly as possible. Should the earth have a tendency to fall in before the bottom is reached, short thick plants are provided, and placed against the loose parts of both sides of the drain in a perpendicular or horizontal position, according to the form of the loose earth, and there kept firm by short stobs, acting as props between the planks on both sides of the drain, as in fig. 401, where *a a* are the sides of the drain, *d d* planks placed perpendicularly against them, and kept in their places by the short prop *c*; or where it is necessary to have the planks placed horizontally, *f* and its opposite neighbour is so placed, and kept in their position by the props *e e*.

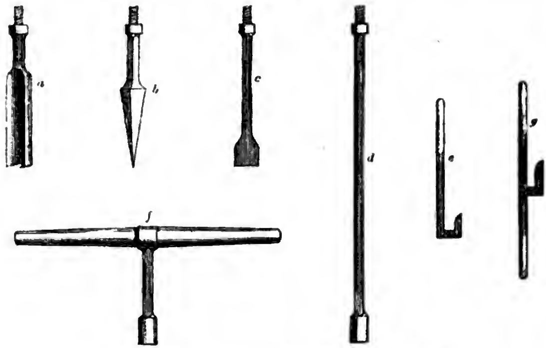
Fig. 401.



THE POSITIONS OF PLANKS AND WEDGES TO PREVENT THE SIDES OF DRAINS FALLING IN.

1103. *Boring-Irons.*—Where it has been ascertained that the strata under a collection of water is gravelly, and the water is retained in its place by an impervious stratum of clay over the gravel, the water will find a vent if a hole be formed through the clay into the gravel, and this is most easily effected by means of boring-rods. The boring-irons are made to open a passage through various sorts of materials, such as impervious clay, thin rock and hard rock; and one or all of these substances may have to be penetrated ere an adequate passage be formed for the detained water to escape. Fig. 402 shows the various instruments used in boring, where (1) the *auger a* is from $2\frac{1}{2}$ to $3\frac{1}{2}$ inches in diameter, and about 16 inches in length in the shell, the sides of which are brought pretty close together. It is used for drilling a hole in the ground, and bringing up the drilled earth. When harder substances than earth are met with, such as compact gravel or thin soft rock, (2) a pyramidal *punch*, *b*, is used to penetrate into and make an opening for the auger. When rock intervenes, then (3) the *chisel* or *jumper*, *c*, is used to cut it through, the face of which should be of greater breadth than the diameter of the auger used afterwards. There are (4) rods of iron *d*, each 3 feet long and 1 inch square, unless at the joints, which

Fig. 402.

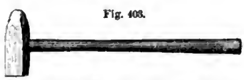


THE INSTRUMENTS FOR BORING THE SUB-STRATA OF DEEP DRAINS.

are $1\frac{1}{2}$ inch in diameter, with a male screw at one end and a female at the other, for screwing into any of the above instruments, or into one another, to make them as long as to allow the descent of any of the instruments into their working place. (5) The short iron *key*, *e*, is used for screwing and unscrewing the rods from the instruments and from one another. (6) A *cross-handle* of wood *f*, having a piece of rod attached to it, with a screw to fasten it to the top of the uppermost rod, is used for the purpose of wrenching round the rods and auger, and for lifting up and letting fall the rods and jumper, when these are used respectively. (7) The long iron key *g* is used to support the rods and instruments as they are let down and taken up, while the rods are screwed on or off with the short key *e*.

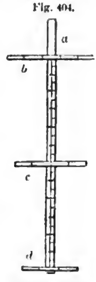
1104. *Hammer for Breaking Stones for Drains.*—Instead of throwing in stones promiscuously large and small into drains, the large ones are broken in order to pack them more firmly together in the drain, and to prevent their shifting in position. Fig. 403 represents a hammer well suited for breaking the larger stones for drains. It consists of a rectangular mass of iron from $4\frac{1}{2}$ lb. to 6 lb. in weight, having one face square and the other rounded like an egg, and both faces are steeled. The shaft is of ash, and about 26 inches in length.

Fig. 403.



HAMMER FOR BREAKING STONES FOR DRAINS.

Fig. 404.

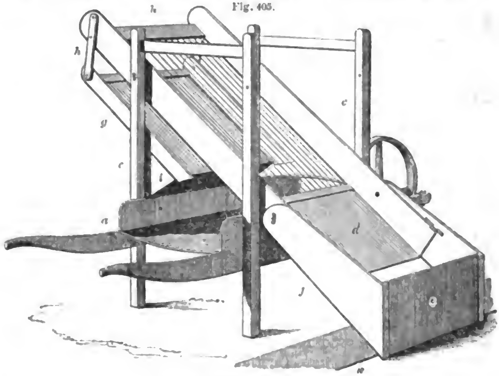


THE DRAIN-GAUGE.

1105. *The Drain-Gauge.*—For the purpose of ascertaining whether drains are cut out of the specified dimensions by the contractors, a drain-gauge proves a handy implement, of which fig. 404 is a representation: *a* is a flat rod of wood, of greater length than the depth of any drain to be cut; it is graduated into feet and inches, commencing the scale from the lower end of the rod. Fillets of wood are screwed on to the rod of such lengths as to correspond to the width of the drain at the top, the middle, and the bottom, such as at *b c d*. The rod *a* is put down by its upper part, which acts as a handle, with the arms *b c d* extending along the drain first to ascertain the depth by the graduated scale; and which being ascertained, the rod is gently turned round, while resting on its lower end on the bottom of the drain, until the points of the arms *b c d* touch both sides of the drain. If the arms cannot come round square to the sides of the drain, the drain is narrower than was intended, which can do no harm; but if they cannot touch both sides, the drain is wider than necessary, and should be objected to, and although the fault cannot be remedied, it may not be repeated. By the constant use of this gauge while the cutting of drains is going on, much unnecessary work may be avoided.

1106. *The Portable Drain-Screen or Harp.*—A portable *screen* or *harp* is

Fig. 405.



THE DRAIN-STONE HARP OR SCREEN.

used for riddling and depositing the stones, as seen in fig. 405, which consists of a wheelbarrow *a*, over and across which is suspended a screen *b*, having the bars more or less apart, according to the description of materials intended to be used. The upper end is hung upon two posts *c c*, about 3 feet above the barrow, the lower end rests upon the opposite side of the barrow. To this lower end is affixed a spout *d*; attached about 10 inches from the lower extremity of which is a board *e*, by means of two arms *f*, and which board *e* is supported at the farther side of the drain at *k* from the barrow *a*. Another screen *g*, about one-half the length of *b*, and having the bars about ½ an inch apart, is hung parallel, about 10 inches below the larger one *b*. The upper end of *g* is fixed by means of two small iron bars *h* to the upper end of the larger screen *b*; the lower end rests upon a board *i* sloping outwards upon the side of the barrow opposite to that on which the spout *d* is situate.

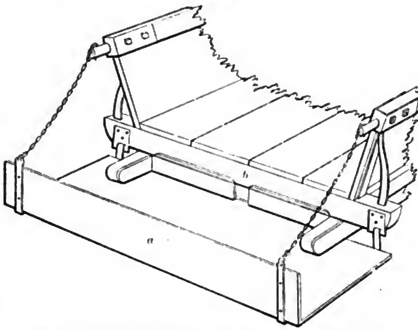
Fig. 406.

THE FRYING-PAN OR LIME SHOVEL.

1107. *The Frying-pan Shovel.*—This is the most convenient form of shovel for supplying drains with small stones, fig. 406. It is heart-shaped, with a blunt point in front, and a raised back for holding in stones, or for protecting the hand when this shovel is used for spreading lime upon land out of carts. Its helve is bent to prevent the greater stooping of the labourer, and it is fixed to a socket, and furnished at top with a short cross-handle. Cost, 3s. 10d.

1108. *A Tail-board for Drain-Stones.*—A movable trough, or, as it is commonly called, a *tail-board*, *a*, fig. 407, is attached to the hind part of a cart, for the purpose of receiving any stones that may drop while the workmen are shovelling them out of the cart. A portion of the hind part of a cart *b* shows the manner in which it is affixed to it.

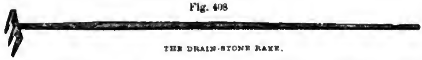
Fig. 407.



THE TAIL-BOARD TROUGH FOR RECEIVING THE DRAIN-STONES IN THEIR FALL.

1109. *Drain-Stone Rake.*—Fig. 408 is a small iron *rake* used by the workman in charge of the drain, for the purpose of bringing the surface of the larger stones to a uniform height before being covered with the smaller.

Fig. 408



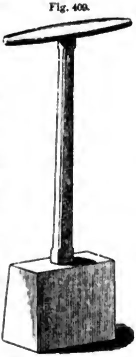
THE DRAIN-STONE RAKE.

1110. *The Drain-Stone Beater.*—Fig. 409 is the drain-stone Roman *beater*, which is a square piece of wood, the width of the drain, used for beating the smaller stones into the interstices of the larger ones, and thus levelling the surface of the stones, and making it compact.

1111. *Draining of Bogs.*—The draining of bogs requires implements peculiarly suited for the purpose. They are not numerous, but efficient.

1112. *The Edging-Iron.*—The easiest mode of lining out the top of a drain in a bog is by following a garden line with the edging-iron, fig. 410. It consists of a crescent-shaped blade, having a sharp face along the segment, and the back not very thick. The helve, furnished with a short cross-head, is about 4 feet long, and is fixed in a socket attached to the blade.

Fig. 409.



THE DRAIN-STONE BEATER.

Fig. 410.

THE EDGING-IRON.

Fig. 411.

THE BROAD-MOUTHED SHOVEL.

1113. *The Broad-mouthed Shovel.*—The first spit after the edging-iron, fig. 410, has cut out the line of the drain in the bog, is best cut and taken out with the broad-mouthed shovel, fig. 411. It consists of a broad thin blade, slightly hollowed in the centre. The helve is slightly curved, furnished with a short cross-head, and fixed into a split hose like the common spade. Being broad and light, this shovel can cast out a very large turf.

1114. *The Horizontal Spade.*—This is a new spade, and is so named because it works in a horizontal direction. Where footing can be found in a bog, this spade is the most efficient implement for cutting out the turf below the first spit cast out by the broad-mouthed shovel, fig. 411. Where no footing is to be had, by reason of the softness of the peat, this spade is not so useful. It consists of a blade of iron, rounded and sharpened in front. The socket attached to the blade is long and bent, so as to keep the blade in a horizontal position while the labourer uses the handle at the ordinary height from the ground. The helve, which is straight, is fixed in the socket, and furnished with a short cross-head.

Fig. 412.

THE HORIZONTAL SPADE.

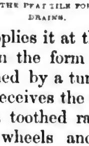
1115. *The Peat-Tile Spade.*—Tiles made of dried peats have been recommended for the drainage of land where peats are near, and tiles and stones distant. In case of such a locality requiring draining, a peat-tile may be made by a spade contrived by Mr Hugh Calderwood, bricklayer, Ayrshire. It consists of an iron cutting-part, fig. 413, of a semi-cylindrical form, furnished with a flange on each edge, and a cutting tongue at the extremity of one of the flanges. It is provided with a cross-headed helve, which is inserted into a socket attached to the cutting part.

Fig. 413.

THE CALDERWOOD PEAT-TILE SPADE-TOOL.

1116. *The Peat-Tile for Drains.*—The tile cut out of the peat by this spade has the appearance represented in fig. 414, where two separate tiles, *a* and *b*, are placed one above the other, leaving a circular opening in the centre between them. One man can cut from 2000 to 3000 such tiles every day, which, after being thoroughly dried by the weather, are fit for use.

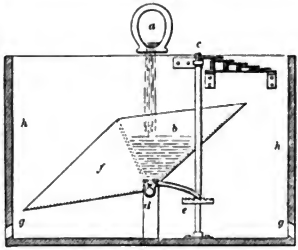
Fig. 414.



THE PEAT-TILE FOR DRAINS.

1117. *The Drain-Water Metre.*—It is desirable at times to ascertain the quantity of water discharged by drains in a given time. Mr Milne Home of Wedderburn, Berwickshire, has contrived a machine by which the discharge of water from drains may be measured accurately enough for all practical purposes. Fig. 415 is a view in vertical section of the drain-water metre, where *a* is the main-tile drain-mouth which discharges the water of the drains, and supplies it at that particular part to the metre; *b f* is a vessel made of sheet-iron in the form of a solid rhomboid, open on two of its sides. The vessel is attached by a tumbling-joint at one of its angles upon an upright iron stud *d*, and it receives the water from the drain *a*; *c* is an upright iron spindle, which carries a toothed rack at its upper end, which sets in motion a series of graduated wheels and racks, that mark the tenths, hundredths, and thousandths of gallons of water discharged in a specified time, the same as does the index of a gas-metre. The vessel *b f* is divided in the middle by a diaphragm represented by the perpendicular dotted lines. When the part *b* becomes full of water, that side of the vessel descends by its gravity towards the bottom of the box *h h* in which it is placed, by turning upon the tumbling-joint at *d*, in doing which it moves the ratchet-wheel *e* on the spindle *c* by means of a short lever attached to the vessel, as shown at *d*. On the vessel descending, it discharges its water from the box by means of the aperture *g*, situated on the right side at the bottom. As the one-half of the vessel *b* descends and empties its water, the other half *f* ascends to receive the water from *a*, and on being filled also descends and discharges the water at the left side of the box through the aperture *g*. When the half *f* of the vessel descends, it does not act on the ratchet-wheel *e*, but simply draws the short lever back over the teeth of the ratchet-wheel, so that the set of wheels and racks at *c* really indicate only half the quantity of water which has been discharged from the drain.

Fig. 415.



THE DRAIN-WATER METRE.

1118. *Paring Implements.*—The common No. 5 garden-spade, fig. 373, with a sharp edge, and its corners a little worn by work, removes the rough herbage of the surface very well, and the turf can be set up at the same time by the workmen to be dried; but the labour of paring and burning in this manner is expensive, and is therefore seldom incurred, although the spade might be usefully employed in some cases in assisting the other means of paring—that is, by the paring-ploughs, as figs. 284 and 285—and its work would then be economical.

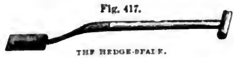
1119. *The Flauchter-Spade.*—A more efficient and expeditious implement for paring turf is a spade of a different form, fig. 416, the face of which is angular and sharp, the blade 9 inches broad and 15 inches long; the right-hand and straight side of which is turned up 3 inches, with a cutting edge in front; the helve is 5 feet long, and flat, provided with a flat cross-handle 2 feet long, with its plane at right angles to that of the helve. The blade of the spade is set at such an angle with the helve, as to permit the handle to be elevated to the height of a man's haunches, when the blade rests on its sole, when at work, flat upon the ground. This instrument is called in Scotland the flauchter-spade, from the Teutonic verb to *flauch* or take off the skin; and the mode of using it will at once show the impropriety of the English term of the *breast-plough*, the breast of the worker never touching it.

Fig. 416.


THE FLAUCHTER-SPADE AT WORK.

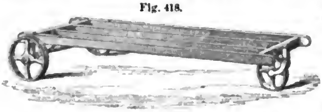
1120. *The Hedge-Spade.*—Fig. 417 represents an implement for paring the face of a hedge-bank of the rank grass that may have grown there. It consists of a rectangular blade, with a sharp face; a socket and stem are attached to the blade, bent as much as to free the labourer's hands from the bank when using the spade. The helve, 2 feet long, and furnished with a short cross-head, is fixed into the socket.

Fig. 417.


THE HEDGE-SPADE.

1121. *Carriage for conveying Harrows, &c.*—In fig. 418 is given an illustration of a carriage for removing harrows from one field to another: it consists of a frame of wood, sparred, in length to take on a pair of harrows coupled with their master swing-tree, and in breadth perhaps 3½ feet. The hind-part of the frame rests on crutches supported upon the axle of two wheels, the upper part of the rim of which is below the level of the top part of the frame; and the fore-part rests upon a castor which allows the carriage to be turned when desired. A horse is yoked to two eyes in the fore-bar of the frame by the hooks of the plough-chains, to draw the carriage by. The harrows are piled one above the other upon the framing. Such a carriage may convey other articles to and from the fields.

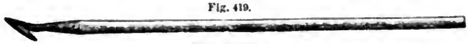
Fig. 418.



THE CARRIAGE FOR CONVEYING HARROWS, &c.

1122. *The Weed-Hook.*—It consists of an acute hook of iron, flattened, of the form of fig. 419, with the two inner edges as far set asunder as to embrace

Fig. 419.



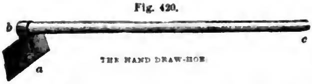
THE WEED-HOOK.

the stem of succulent herbaceous plants, and made as sharp as easily to cut through them. The cutting-hook is attached to a neck of iron, which is forged at the other extremity into the form of a socket, to take in the end of a light wooden handle about 4 feet in length, to which it is fastened by means of a nail or screw. The neck is bent in the form that, when the under surface of the hook rests upon the ground, the handle shall be so inclined as to suit the hand of the worker. The weed-hook is used with one hand, the worker walking upright, and holding it by the handle before her in an inclined position towards the ground, and drawing it towards her with a jerk. Cost, 6d.

1123. We have seen a weed-hook with its outer edge also sharpened, for cutting weeds with a push forwards; but such a one cannot be used amongst standing corn, since its sharp outer edge would inevitably cut its stems.

1124. *The Hand Draw-Hoe.*—The hand draw-hoe, fig. 420, consists of a thin iron plate *a*, faced with steel, 7 inches in length and 4 inches in breadth, with an eye *b* to receive the handle *c*, usually made of fir, to make the implement as light in the hand as possible.

Fig. 420.

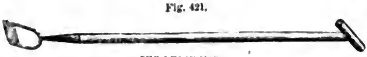


THE HAND DRAW-HOE.

The hand draw-hoe is used for weeding corn sown in rows, as also for singling turnips. In weeding corn it is used by field-workers, who each take a drill, and hoe the ground between the rows, and when the corn is dibbled, between the plants also. In weeding rowed corn it is necessary for the field-workers each to occupy a row; and to prevent their jostling one another, the one in the centre of the band takes the lead in an advanced position, while the others range themselves on each side in echelon. In singling turnips the shaft *c* of the hoe should not exceed 3 feet in length, although in some parts of the country it is 4½ feet, whilst in others it is 33 inches. The shorter the shaft is, the better for the work, as it enables the worker to stoop closer to the ground, although that position is severe upon the worker.

1125. *The Dutch-Hoe.*—The Dutch-hoe, fig. 421, consists of a thin plate of iron steeled on the face, 7 inches in length, having its two extremities connected with a bow of iron rod, to which is attached a socket, into which the handle, 5 feet in length, furnished with an oblique

Fig. 421.

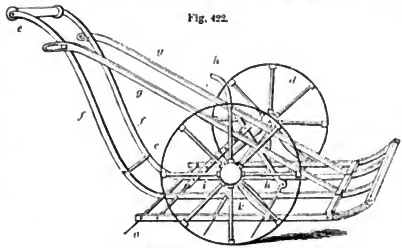


THE DUTCH HOE.

cross-head, is fixed. It is used by a push forwards, and is useful in weeding the face and top of the bank behind a hedge.

1126. *Turnip-Fly Catcher.*—In fig. 422 we give a view in perspective of a turnip-fly catcher, patented by Mr Morris, and manufactured by Messrs Banks and Nixon, Nottingham. It consists of a light horizontal framework *a b*, carried by two wheels *c d*, and guided and propelled by the handle *e f f*, the two side-bars of which, *f f*, are a continuation of two of the horizontal bars of the frame *a b*. Two diagonal stays, *g g*, connect the fore part of the frame *a b* with the handle-bars *f f*, and are provided with slots at their upper end. These slots slide on bolts connected to the handle-bars *f f*, and admit of adjustment at various points. The height of the frame *a b* from the ground is adjusted by means of the lever *h h*, the lower end of which is connected with a bar of the frame *a b*. The lever is adjusted at any desired angle by a pin or bolt passing into an aperture in the bar *i*, fixed at its lower end to one of the bars of the frame *a b*. The wheels *c d* run in bearings in the upper part of the bars *k*, the lower ends of which are jointed to the sides of the frame *a b*. As the handle *e* is depressed, the lower end of the diagonal stays *g g* is elevated, and this raises the lower ends of the bars *k*, and depresses their upper, thereby raising the frame *a b* farther from the ground, and *vice versâ*.

Fig. 422.

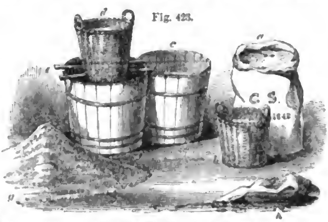


THE TURNIP-FLY CATCHER.

1127. To the under side of the frame *a b*, a curtain of light canvass is attached, the lower surface of which is smeared with an adhesive compound. As the machine is propelled forward along the drill of turnip-plants affected by the turnip-fly, the curtain brushes up the insects from off the plants, and carries them away adhering to the adhesive compound.

1128. *Pickling Apparatus for Wheat.*—To insure wheat from the attacks of fungal disease, it is considered advisable to "pickle" it—that is, subject it to a preparation in a certain kind of liquor immediately before it is sown. In fig. 423 we illustrate the apparatus used for this purpose, where *a* is the sack of wheat to be pickled, *b* the basket into which the wheat is put, *c* is the tub which contains the pickle, and into which the basket *b* is immersed in the pickle; *d* is the basket containing the pickled wheat, set upon the drainer *e*, over the tub *f*, to drip the superfluous pickle into; *g* is the heap of pickled wheat, and *h* are the empty sacks to contain the pickled wheat for sowing.

Fig. 423.



PICKLING APPARATUS FOR WHEAT.

1129. *The Seed Rusky.*—Fig. 424 is the seed-rusky or basket for carrying the seed in the field from the sacks to the sower. It is usually made of twisted straw laid in rows above each other, and fastened together by means of withes of willow. It is provided with a couple of handles of the same material, sufficient to admit the points of the fingers, and also a rim around the bottom, upon which it stands.

Fig. 424.

THE SEED-CORN RUSKY.

1130. *The Sowing-Sheet.*—The *sower* is habited in a peculiar manner; he puts on a sowing-sheet made of linen. The most convenient form of *sowing-sheet* is that of a semi-spheroid, having an opening at one side of its mouth large enough to allow the head and right arm to pass through, and by which it is suspended over the left shoulder. On distending its mouth with both hands, and on receiving the seed into it, the superfluous portion of the sheet is wound over the left arm and gathered into the left hand, by which it is held tightly, while the load of corn is securely supported by that part of it which passes over the left shoulder across the back and under the right arm. The right arm, which throws the seed, finds easy access to the corn from the comparatively loose side of the mouth of the sheet, between the left hand and the body of the sower.

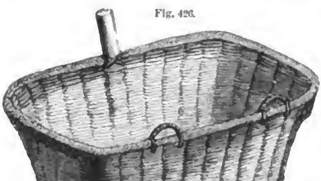
Fig. 425.

SEED SOWING FROM THE SOWING SHEET.

1131. A square sheet, knotted together in three of its corners, and put on in a similar manner, is sometimes used as a sowing-sheet; but one formed and sewed of the proper shape, and kept for the purpose, is a much better article.

1132. Linen sheeting makes an excellent material for a sowing-sheet, and when washed at the end of the sowing season, will last many years. The difficult point is to make the sowing-sheet fit the top of the left shoulder of the sower, where the greater part of the weight of the corn is felt; and, in accomplishing this, the principal thing to be considered is, to make the plain part, which lies upon the shoulder, broad enough, and to slope it with the shape of the shoulder. The gatherings of the cloth on each side of the shoulder-top should be flatly executed, and a couple of tapes placed in a slot-hem in front of the sheet across the breast.

Fig. 426.



THE ENGLISH SOWING BASKET.

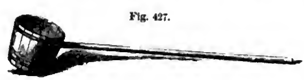
1133. *The English Sowing-Basket.*—A basket of wicker-work, such as in fig. 426, is very commonly used in England for sowing seed. It is suspended by girthing, fastened to the two loops shown in the figure, on the rim of the basket, and passed either over the left shoulder and under the right arm, or round the back of the neck; and the left hand holds it steady by the head of the wooden stave shown on the other side of the basket from the loops.

1134. *Double-handed Sowing Apparatus.*—Some sowers throw the seed with both hands, and then the instrument must be made to suit the practice. In this case a linen sheet will not answer; a basket or box made of thin deal, having a curved form to suit the front of the body, should be used. It is fastened round the body by a strap and buckle, and is suspended besides by girthing fastened to loops on the side next the sower, and passed round the back of his neck; and the further side is suspended by a strap passing upwards towards the chin of the sower, where it divides into two, and passes over both shoulders, and is made fast to the strap buckled round the body.

1135. A more simple form of sowing-sheet for both hands is a linen bag attached to a rim of iron-rod, made to suit the form of the body, buckled round it, and suspended in front in the manner described in par. 1134. In either construction both hands are at liberty to cast the seed.

1136. *The Scoop for filling Water-Barrels.*—Fig. 427 represents a convenient form of scoop for filling water-barrels at a spring or rivulet. It consists of a small tub of cooper-work, hooped with iron, and furnished with a shaft long enough to enable the workman to reach from the water to the funnel of the barrel.

Fig. 427.



THE SCOOP FOR FILLING THE WATER-BARREL.

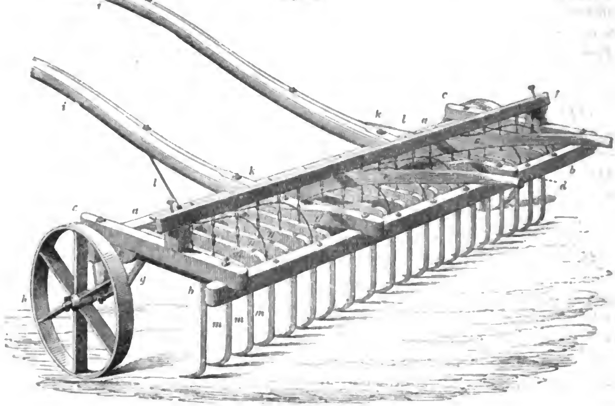
DIVISION SECOND.—IMPLEMENTS AND MACHINES CONNECTED WITH THE PRODUCTS OF THE SOIL.

1137. SECTION FIRST—*Hay-Making Machines.*

1138. *The Horse-Rake.*—The horse-rake is an implement much used for collecting the hay into heaps. The varieties of it are numerous, but all possess the properties of collecting to a certain amount, and then, by a simple operation of the hand, dropping in a collected mass the quantity of hay or straw thus accumulated in the machine.

1139. One of the most common forms of the horse-rake is represented in perspective by fig. 428, and somewhat more in detail by fig. 429, which is a longitudinal section of the body and adjoining parts, the same letters marking corresponding parts in the two figures. The body of the machine consists of a main beam *a a*, 9 feet long and 3 inches square, and another a swing-bar *b b* of equal length, but only $2\frac{1}{4}$ inches square, and these are bolted together upon two side-bars *c c*, also $2\frac{1}{4}$ inches square, but only 2 feet 9 inches long, and the main beam *a* and swing-bar *b* are further supported by two intermediate bars *d d*, which, in the vertical direction, are bent as seen in section, fig. 429; these, at their junction with the main beam, are tenoned instead of being bolted, but are bolted upon the swing-bar. A pair of handles, *e e*, are jointed upon the thorough-bolt *n*, fig. 429, and are bolted to the lifting-bar *f*, which *rests* at each end on wooden nogs tenoned into the swing-bars *c c*, and the ends of the lifting-bar *f* are each furnished with a thumb-screw for adjusting the height of the bar. The axles *g* are kneed to stand 5 inches below the main beam *a*, and are bolted to it directly at the tail of the axle, and also through the stud-bracket at the neck. The wheels *h* are 20 inches diameter, of light make in cast-iron, and the horse-shafts *i i*, worked to such a curvature that they shall

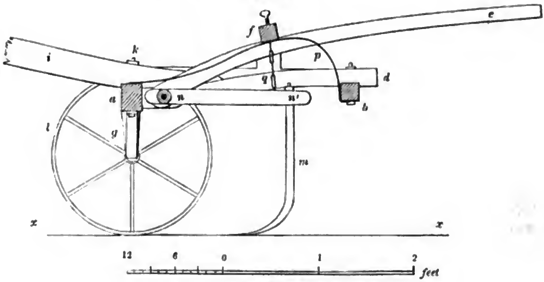
Fig. 428.



THE HAY AND STUBBLE HORSE-RAKE.

be of the proper height for the horses' shoulders when the body of the implement stands level, are bolted to the main beam *a* and intermediate bars *d* at *k*; and are likewise supported by the iron stays *l l*. It is also to be observed, that in both figures the horse-shafts *i i* are partially or altogether broken off for want of space. The machine is armed with twenty tines or teeth *m m*, &c., which are 18 inches high from the ground-line *x x*, fig. 429, to the upper edge of the

Fig. 429.



SECTION AND SCALE OF THE HAY AND STUBBLE HORSE-RAKE.

rake-head *n n′*, each tooth being fixed into a separate head with a screwed tail and nut, while at the point they are bent forward and sharpened, but are adjusted so as not to run into the ground. The rake-heads are threaded upon the bolt *n*, which extends from side to side of the machine, and between each two rake-heads a wooden stretcher-roller is applied, preserving the heads at the proper distance, and through these, as well as the handles *e e*, the bolt *n* also passes. Seven stripping-rods *p*, bent as in fig. 429, are attached to the main beam *a* and the swing-bar *b* by bolts, and each of the rake-heads *n'* are attached to the lifting-bar *f* by means of a short chain *q*, whereby, when the handles *e* are lifted, the bar *f* and all the rake-tines are lifted from the ground by one operation; and when let down again till the lifting-bar *f*, or its adjusting screws, rest on their studs, each tine is then at liberty to rise and fall a small space, as the inequality of the ground or any obstruction may require.

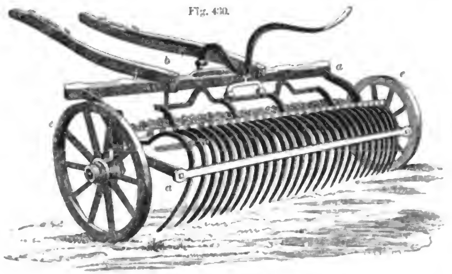
1140. In the act of working, the machine advances till the tines *m* have collected as much hay or straw as can be contained in the bosom of the tines and heads; and when thus filled, the attendant, by lifting the handles *e*, causes the tines to be drawn upward through amongst the stripping-rods *p*, which discharge the contents of the rake upon the ground; the handles *e* are immediately let down to the working position, and the work proceeds as before.

1141. As a stubble-rake this horse-rake is in very general use, and is highly prized from its efficiency in gleaning stubbles.

1142. The usual price of this horse-rake is from £3, 10s. to £3, 15s.

1143. *Smith's Counterbalance Horse-Rake.*—Amongst the many varieties of patent horse-rakes now in use, may be noticed that of Mr Thomas Smith of Bradfield, Suffolk, as possessing arrangements of simplicity and efficiency. The principal feature of the invention is, combining with the tines or teeth counterbalance-weights; these tend to raise the teeth from the land, and prevent them from sinking in and doing injury to the ground—an objection which obtains against some forms of rakes. By the arrangement here adopted, due strength can be given to the tines without increasing their pressure on the land; and the whole, by a simple system of levers, are easily thrown out of contact with the material operated upon. In fig. 430 we give a perspective

Fig. 430.



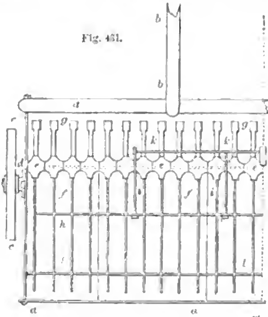
SMITH'S COUNTERBALANCE HORSE-RAKE.

view of this machine, in fig. 431 a plan of half, in fig. 432 a side view, and in fig. 433 a vertical section through the dotted central line at *m* in fig. 431.

1144. The following is a description of the arrangement and operation of the various parts: The frame *a a*, fig. 430, and shafts *b*, are made of wrought-iron, and are mounted upon wheels *e e*, 1 foot 7 inches diameter, these being capable of being raised or lowered as required. A central bar or axis *d d*, fig. 431, connects the two side-frames *a a*, and carries a series of bosses *e e*, &c. These bosses are provided with projections at the two extremities of the diameter, to which the tines *f f*, &c. are bolted on one side, and the counterbalance-weights and levers *g g*, &c., on the other.

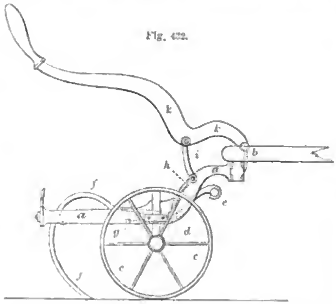
1145. The tines *f f*, &c. rest upon a bar *h h*, fig. 431, parallel to the axis *d d*; four levers *i i i i* are provided with eyes through which the central axis *d* passes.

Fig. 431.



PLAN OF COUNTERBALANCE HORSE-RAKE—SCALE, ½ INCH TO THE FOOT.

Fig. 432.

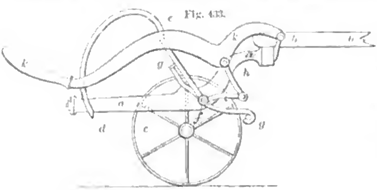


END ELEVATION OF HORSE-RAKE—SCALE, ½ INCH TO THE FOOT

The extremities of the longest arms of these levers are fixed to the bar *h h*, those of the shortest arms to the bar *k k*. To the centre of this bar *k k* a lever, fig. 432, is jointed, the upper extremity of which is jointed to the main handle or working-lever *k k*.

1146. When it is required to lift the tines out of contact with the ground, the outer extremity of the lever *k k*, fig. 432, is depressed; this bears down the lever *i*, which, acting on the bar *k k*, fig. 431, depresses it, and with it the short arms of the levers *i i*, the long arms of which are raised, and with them the bar *h h*, on which the tines *f f* rest. From the action of the counterbalance-weights *g g*, the tines are raised with great ease. As they pass upwards they are cleared from the hay by the action of the clearer-rod *l l*, fig. 431.

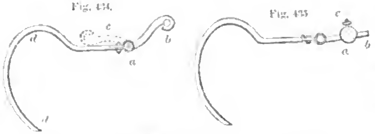
Fig. 433.



SECTION OF COUNTERBALANCE HORSE-RAKE—SCALE, ½ INCH TO THE FOOT.

1147. Where the pressure of the tines on the land is required to be increased, the counterbalance-weights are attached to the levers, as shown in fig. 434, a joint being made at *a* to enable the weight *b* and lever *c* to be turned back, resting upon the tine *d d*, as shown by the dotted lines. Another method of adjusting the pressure on the tines is shown at fig. 435, where the weight *a* is adjusted at any point of the length of the lever *b* by the pinching-screw *c*.

Fig. 434. Fig. 435



DETAILS OF TINE OF HORSE-RAKE—SCALE ½ INCH TO THE FOOT

1148. With a rake 7 feet 6 inches wide, the price of the implement is

£7, 10s.; when the width of the rake is 9 feet 3 inches, the price is £8, 15s. The price of the shifting counterbalance-weight, as in fig. 435, is 8s. extra.

1149. *The Hay-tedding Machine.*—We have now to notice the hay-tedding machine, which is extensively employed by the English farmers in the preparation of *meadow*-hay, prepared from the mixed natural grasses, in contradistinction from the artificial rye-grass and clover hay. The modes of saving or winning these two kinds of hay are different even in England, where haymaking is best understood; while in Scotland all hay-making is decidedly bad, rye-grass hay being the chief kind of hay in Scotland. But it is highly probable that rye-grass hay might be prepared by the English method, greatly to the advantage of its nutritive qualities.

1150. The chief objection to the hay-tedding machine in Scotland is, that, in the peculiarity of its action, it scatters the seed out of the rye-grass. The objection originates in the perseverance of a bad method of raising hay. When the rye-grass is allowed to stand so long before it is mowed as to ripen its seed, it has stood too long to become good hay. When the rye-grass is mown in its best state for hay, there is no seed in it to scatter abroad. When rye-grass is grown for the sake of its seed, it should be treated in an entirely different manner from what it should be when made into hay. The tedding-machine, in truth, is just as capable of making good hay in Scotland as in England.

1151. *The English Hay-tedding Machine.*—A form of this machine is given in perspective in Plate XVI., fig. 2, consisting of a skeleton carriage, and having a series of revolving rakes occupying the place of the body. The carriage is composed of the transverse bar *a*, 6 feet in length, into which the horse-shafts *b b* are tenoned. An iron stay-bar *c c* on each side connects and supports the shafts, and the stays are continued backward, and attached to the centre of the box that carries the axle of the carriage-wheel on each side. The length of the bars *c*, from *a* to the centre of the axle-box, is 3 feet 10 inches, and the bars are 2½ inches by ½ inch. The carriage-wheels *d d* are 3 feet 10 inches diameter, and turn upon arms cast on a circular box, into which the nave of the wheel, armed with a ratchet *e*, is received. The ratchet-wheel *e*, thus attached to the nave of the carriage-wheel, takes hold of the spur-wheel *f* by means of a pawl, and carries it round when the machine advances, but slips hold on backing or turning. The spur-wheel *f* works into the pinion *g*, which is mounted on the end of the hollow shaft *h*, extending from side to side of the machine; and though in the figure, for the sake of distinctness, the spur-wheel and pinion are exposed to view, they are in the machine closely boxed up in a cast-iron casing, which, for perfect and safe working, is necessary to prevent entanglement from the hay falling between the wheel and pinion. A connecting-bar of 1½ inch round iron passes through the hollow shaft *h*, and has its end fitted tightly into the outward side of the case that contains the pinion *g*, and there fixed firmly with a screw-nut on the outside of the case; and the hollow shaft and pinions being firmly connected by thin flanges (which are left out of the figure), they revolve round the central rod or shaft as one body, the rod having turned bearings where the pinion embraces it.

1152. The two rake-wheels *i i* are 2 feet 8 inches diameter, and of very light construction; they have eyes sufficiently large to pass over the end flanges, of about 6 inches diameter, of the hollow shaft *h*, to which the pinions *g* are attached by means of their flanges; and, to fill up the large eyes of the rake-wheels, the shaft *h* is swelled out at the points of bearing. The rake-wheels, fixed dead upon the shaft *h*, are now armed with the eight rakes *k k*; these are wooden bars 5 feet 6 inches long, and 2¼ inches square, each carrying ten light iron teeth, about 7 inches in length. The rakes are attached to the wheels by a tumbling-joint *m*, and are held to the work by the springs *l l* only; by which arrangement, when any undue resistance is opposed to a rake, such as a stone or other obstruction, the rake falls back till the obstruction has been passed, when the springs immediately return it to its working position.

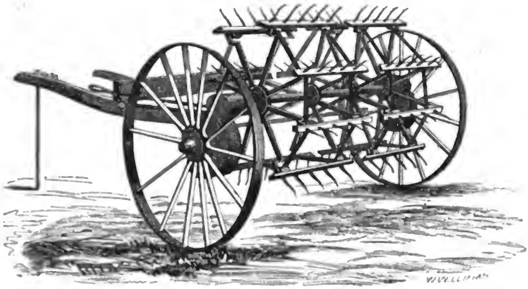
1153. It will be observed that there is no thorough-axle in the machine, as the revolution of the rake occupies the place where that member should exist; hence the axle-arms or heads are simply studs projecting from the box which contains the machinery *e f g*, and hence also the necessity for the connecting-bar which passes through the hollow shaft; that, together with the transverse bar *a* and the stay bars *c c*, being the only parts which constitute the framework of the machine.

1154. Besides the capability of backing, without turning the rakes, there is provision for disengaging them when the machine is advancing. To effect this, the pawl which is attached to the spur-wheel *f*, for the purpose of deriving its motion from the ratchet-wheel *e* of the nave, is held in action by means of a spring pressing on the tail of the pawl, and the disengagement of the whole machinery from the carriage-wheel or first mover is effected by a small tumbling-lever affixed also to the spur-wheel, and fitted to bear upon and throw the pawl out of gear with the ratchet of the carriage-wheel nave. The machine is also furnished with the means of elevating and depressing the centre of the revolving-rake, and, of consequence, bringing the rake-teeth nearer to, or farther from, the ground, and this is effected by turning round the circular boxes that contain the gearing to the extent required, which is then fixed by means of a quadrant bolted to the bars *c c*; a small portion of this quadrant, which is a part or flange of the gearing-box, is seen with its bolt-holes at *e* on the left, and at *i* on the right of the figure.

1155. When in operation the machine is drawn by one horse, or sometimes two horses, and the result of the combination of the gearing is, that the revolving-rake makes 4½ revolutions for one of the carriage-wheel. The latter, being 3 feet 10 inches diameter, will pass over 12 feet or thereby in one revolution, and the rakes being 4 feet 6 inches diameter over the extreme points of the teeth, will describe a circle of about 14 feet in circumference, and this revolving 4½ times for one of the other, the points of the teeth will pass through 63 feet while the carriage has moved over 12 feet, and as there are eight rake-heads, there will be $8 \times 4.5 = 36$ contacts with the substance which is to be lifted, in a space of 12 feet, or one at every 4 inches. From this calculation it will be seen that the hay under the operation of this machine will undergo a process of teazling or tedding of the most perfect description; it will be separated and tossed about until no two stems of the plants will be left in contact, and by this exposure the drying process is effected in a period greatly shorter and more effectually than could be done by any number of hands. Thus, if we suppose the horse to walk 2½ miles per hour, and the machine to cover 6 feet in breadth, we have a surface of 1½ acre nearly covered in an hour.

1156. *Smith and Ashby's Hay-tedding Machine.*—We have now to illustrate and describe a hay-tedding machine which enjoys a high reputation—namely, that of Messrs Smith and Ashby of Stamford. Of this we give a perspective view in fig. 436. By referring to fig. 2, Plate XVI., the reader will perceive that the rakes *k k* are in one piece, stretching from side to side of the machine. In the improved machines, as in fig. 436, the rakes are fixed to two sets of revolving frames, each frame being worked by separate gearing at each end of the machine. By this arrangement, when turning, the outer

Fig. 436.



SMITH AND ASHBY'S HAY-TEDDING MACHINE IN PERSPECTIVE.

wheel keeps one-half of the rakes in motion; whereas, in the old method, in that above noticed in par. 1151, wherever the turning occurred in the working-wheel, the machine necessarily missed its work.

1157. In the early machines, "tedding," or turning the hay under and completely over the machine, was the only operation intended to be performed by them. Now, however, another process in hay-making by machine is required, namely, slightly raising from the ground and scattering behind the machine the hay which was deposited by the complete turning-over action of the machine in the first instance. There are thus two actions—one the "forward," in which the hay is lifted from the ground and turned completely over; the other the "backward," in which the hay is scattered very lightly from behind the machine, not turned over. Messrs Smith and Ashby's machine is furnished with this reversing action.

1158. In the machine now under consideration, each tine in the revolving frame is supported by double bearings of wrought-iron, and is fitted with two strong steel springs: this arrangement enables the heaviest crops to be thrown up without clogging. In fig. 437 we give a detail figure of a tooth or tine. Part of the tine or traverse bar, which supports five teeth (as shown in fig. 436), is shown at *a b*; *c d* is part of a spring, the end of which towards *d* is fixed to the head of the preceding cross or traverse bar, the other end being free, and pressing upon the shoe *e f*; *g* is the tooth or tine resting upon the spring: its upper end passes through the bar *a b* and the iron shoe *e f*, and is secured by a nut as shown. The traverse bar *a b* is jointed at the ends to the radial bars of the revolving frame, so that it is capable of being moved round in manner like a shaft. By taking hold of the extremity of the tooth *g* and pulling it outwards, the bar *a b* rotates on its centre, and makes the point *e* of the shoe *f* describe an arc of a circle, the end of the spring *c* still pressing upon the back of the shoe till the outer point *f* comes in contact with the end of the spring *c*. In this position the end of the tooth *g* is placed upwards, the assemblage of teeth on the cross bars being ready for work

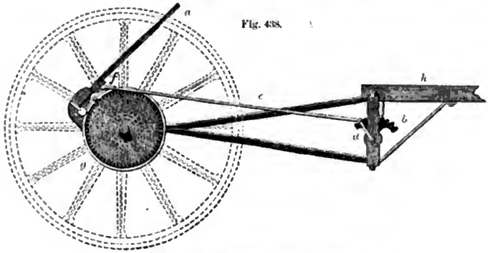
Fig. 437.

TINE OF SMITH AND ASHBY'S HAY-TEDDING MACHINE.

as shown in fig. 436. When the tines meet any obstruction while working, the springs give way and allow the points of the tines to pass over. In addition to those two positions of which the tines are capable, a third can be given to them by carrying the bar *a b*, fig. 437, further round in the direction of *c*.

1159. The driving-gear is very similar to that of the machine in fig. 2, Plate XVI. In fig. 438, which is part of a longitudinal section of Messrs Smith and Ashby's machine, now under consideration, *a* shows the lever (broken off)

Fig. 438.



PART SECTION OF SMITH AND ASHBY'S HAY-TEDDING MACHINE

which is within the control of the driver. This acts upon a long rod, which passes through the hollow main-shaft, and moves the wheels at each side of the machine, and puts them at the same time in and out of gear.

1160. Another feature in the machine is the mechanism by which the revolving frames are raised from or lowered to the ground as desired. This is shown in fig. 438. To the bracket *c*, attached near the end of the driving-shaft *h*, and which is strengthened by the triangular stays as shown, an endless screw works; this engages with the teeth of a segmental rack *b*, the spindle of which works on a stud in the bracket *c*. To the end of the spindle of this rack a lever *d* is keyed, the upper extremity of which is jointed to the end of the lever *e*. The further extremity of this lever *e* is jointed to a stud *f* fixed in the case or cap *g*, which contains the driving-gear that gives motion to the revolving frames. By working the handle of the endless screw in one direction, the end of the lever *d* is made to traverse outwards towards *b*, pulling the lever *e*, and causing the stud *f*, and the case to which it is attached, to move towards *b*: this raises the central shaft of the revolving frames further from the ground; but by turning the handle in the reverse direction, the end of the lever *d* moves inwards from the point *b*, and, pushing the stud *f* in the direction opposite to *b*, the central axis of the revolving frame is placed nearer to the ground.

1161. In this form of hay-tedding machine, the length of the tine-bars, supporting each five tines or teeth, is 2 feet $6\frac{3}{4}$ inches, the section of the bar being 2 inches by 1 inch. The bars are placed in a circle, as shown in the perspective, fig. 436, eight bars being the number in each circle, $11\frac{1}{2}$ inches being the distance between the bars. The distance between the two frames bearing the tines is 4 inches—the total breadth taken up by the two frames being thus 5 feet $5\frac{1}{2}$ inches. The driving-wheels are 3 feet 9 inches in diameter; the tine is made of wrought-iron, $1\frac{3}{4}$ in breadth and $\frac{3}{8}$ inch in thickness.

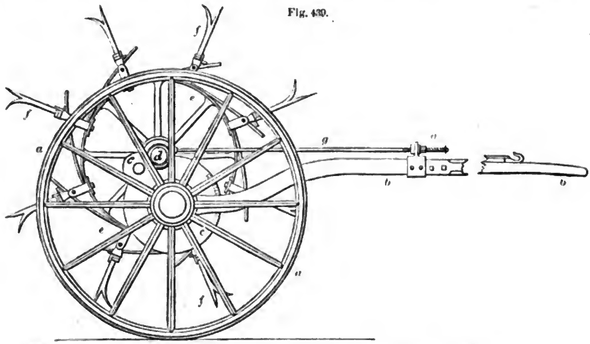
1162. Malleable iron being used principally in the construction of this machine, it is at the same time light and strong.

1163. The nave of the travelling-wheel is formed so as to hold a supply of oil, and is rounded off to prevent hay lodging.

1164. The price of Smith and Ashby's hay-tedding machine is £15, 15s.

1165. *Thompson's Hay-Tedding Machine.* — Of the numerous varieties of recently-patented "tedding" or hay-making machines, we select for illustration that of Mr H. A. Thompson, of Lewes, as exhibiting some commendable features in mechanical construction and arrangement, and of which, in fig. 439, we give a side elevation, drawn to a scale of half an inch to the foot. In

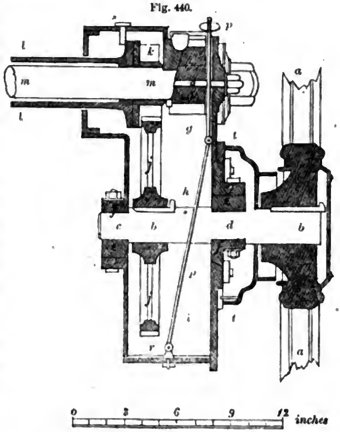
Fig. 439.



THOMPSON'S HAY-TEDDING MACHINE, SIDE ELEVATION—SCALE, ½ INCH TO THE FOOT

fig. 439 *a a* are the travelling-wheels, *b b* the horse-shafts, *c c* the cap or case containing the gearing, *d* the shaft of the tine-barrel *e e*, *f f* the tines, *g g* the set screw by which the height of the tine-barrel *e e* from the ground is regulated.

Fig. 440.



SECTION OF GEARING OF THOMPSON'S HAY-TEDDING MACHINE.

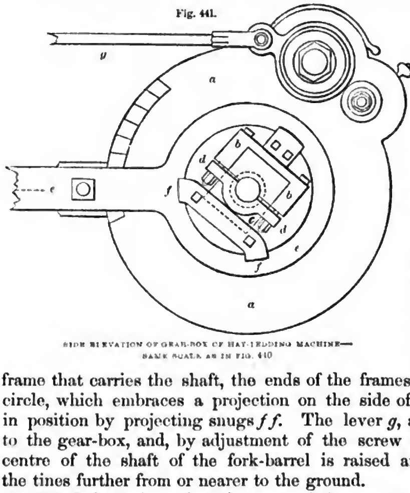
1166. The principal feature in the machine is the adaptation of solid axles to the travelling and working gear; these revolving in bearings capable of adjustment, so that as the parts of the working gear are affected by wear and tear, they can be readily readjusted to work efficiently together.

1167. In fig. 440 we give a transverse section, showing the working parts: *a a* part of the travelling wheel, which is keyed on to the solid axle *b b*, on which two journals *c* and *d* are turned down. The axle revolves in bearings *e f*, *e f*, capable of adjustment, as the journals wear, in the manner usually adopted in machine and mill gearing. These bearings are attached to the gear-box *g h i*, which forms part of the framing of the machine. To the axle *c b*, *d b*, a spur-wheel *j j* is keyed; this engages with a pinion *k*, forming part of the hollow barrel *l l*, which carries the forks or tines *f f*, fig. 439. *m m*, fig. 440, is the axle-bar on which the fork-barrel *l l* revolves.

1168. In the machine now under consideration, the reverse movement of the fork-barrel *l l*, fig. 440, is obtained by the intermediate pinion *n*; this revolves in and slides along the bolt or stud *o*, and is placed in and out of gear by means of the clutch-lever *p*, jointed at its lower extremity to a stud *r* attached to the gear-box *g h i*. The pinion *k* is kept in gear with the wheel *j j* by the locking-piece *s*. A light cap *t t* covers the projecting parts, and prevents hay entangling in them.

1169. In fig. 441 we give a drawing of the side elevation of the gear-box *a a*, with the cap *t t*, fig. 440, removed. *b b*, fig. 441, are the two projecting pieces, between which the bearings or bushes—in which the journals *c d* of the shaft *c b*, *d b*, fig. 440, revolve—are placed. The bearings or bushes *e f*, *e f*, fig. 440, are inserted in their place through the aperture *c*, fig. 441, left in the side-frame, which is filled by a square projection attached to the lower coupling-piece *d d*. To allow of the necessary adjustment of the distance of the tines from the ground, and to attach the frame that carries the shaft, the ends of the frames *e e* are each formed into a circle, which embraces a projection on the side of the gear-box *a a*, and kept in position by projecting snugs *f f*. The lever *g*, and *g g*, fig. 439, is attached to the gear-box, and, by adjustment of the screw at its outer extremity, the centre of the shaft of the fork-barrel is raised and depressed, thus bringing the tines further from or nearer to the ground.

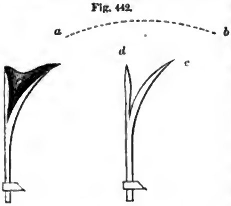
Fig. 441.



SIDE ELEVATION OF GEAR-BOX OF HAY-TEDDING MACHINE—SAME SCALE AS IN FIG. 440.

1170. It is obvious that the form of tine, as in fig. 2, Plate XVI., which is capable of turning over the hay under action of the forward movement of the machine, noticed in the beginning of paragraph 1157, will not be well adapted for the more simple action of the reverse or backward movement. To adapt the fork or tine to its double duty, Mr Thompson has introduced the form illustrated in fig. 442: one of the tines, *c*, is curved in the usual way; the other, *d*, is straight, or but slightly curved. The tine *c* presents a curved surface in revolving in the direction from *b* to *a*; but the tine *d* presents only a very slightly curved surface when revolving in the opposite direction from *a* to *b*. In place of forming the double tine by welding or connecting the two tines *c d* together, the two parts may be made solid by a thin web of metal as at *e*.

Fig. 442.

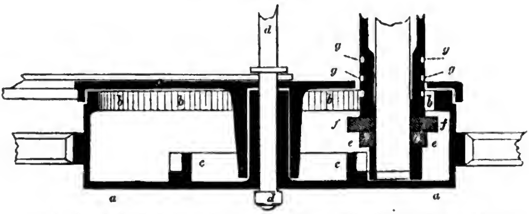


TINES OF THOMPSON'S HAY-TEDDING MACHINE.

1171. The price of Thompson's hay-tedding machine is £15, 15s.

1172. *Nicholson's Hay-tedding Machine.*—The principal feature in the mechanism of the hay-making machine invented by Mr William Newzam Nicholson, of Newark, and which took the principal prize at the meeting of the Royal Agricultural Society at Salisbury in 1857, is the substitution of annular gearing, by which the reverse motion of the fork-barrel or frame is obtained in place of the intermediate pinion as used in the machines generally employed. The axle-box is in the form of a drum, *a a*, fig. 443, or cylindrical case, to the outer periphery of which the spokes of the main driving-wheel are

Fig. 443.



SECTION OF GEARING-BOX OF NICHOLSON'S HAY-TEDDING MACHINE—SCALE, 1½ INCH TO THE FOOT.

fixed. This case contains an annular-wheel *b b*, and a spur-wheel *c c*, these being fixed to opposite sides of the case; *d d* the main axle. The axis *g g* of the fork-carrying-wheel is supported in the cylindrical casing at a point above and to the left of the central axis of the driving-wheel. To the axis of the fork-carrying-wheel two pinions, *e e*, *f f*, are keyed; one of which *e e* engages with the spur-wheel *c c*, the other *f f* with the annular or internal wheel *b b* of the cylindrical case or axle-box *a a*. When the machine is merely travelling from place to place, and the forks not required to be in operation, none of these pinions engage with the spur or annular wheel, but are kept in a position midway between them, as shown in the figure; but by moving the fork-carrying axis to the right, the pinion *e e* is put in gear with the spur-wheel *c c* which gives the fork-carrying axis *g g* the forward motion; by moving the axis *g g* to the left, the wheel *e e* is taken out of gear with the spur-wheel *c c*, and the pinion *f f* put in gear with the annular-wheel *b b*, when the fork-carrying axis *g g* has the backward motion. The fork-carrying axis *g g* is kept in any of the three positions by the catches *g g*.

1173. The position of the axis *g g*, relatively to the ground, is changed by a simple arrangement. The inside cover of the axle-box is lengthened out so as to form a long lever; the extremity of this is finished with a small segmental rack; a pinion with two or more teeth engages with this, the spindle to which the pinion is fixed being worked by a small lever. To work both sides of the machine simultaneously, the rod carrying the pinion is extended across the machine, and a similar apparatus is provided at the other side.

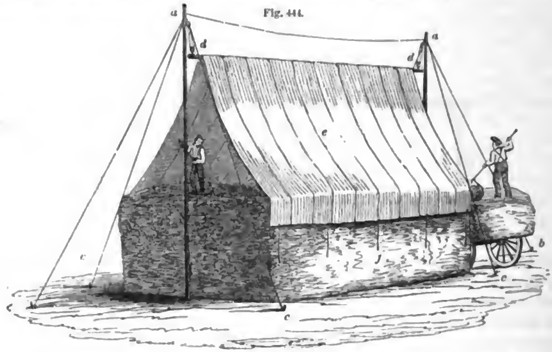
1174. A commendable feature in Nicholson's hay-tedding machine is the employment of tubular iron for the shafts.

1175. The price of Nicholson's hay-tedding machine, with patent tubular shafts, is £15.

1176. *The Rick-Cloth.*—The rick-cloth is an important article in the English farmer's stock in trade, not so much for its value as for its usefulness, and the extension of its use amongst farmers in general is a matter deserving of consideration. It is of essential service to the hay-maker on the English system in the building of his large hay-stacks or ricks, since by its use, when spread over the stack, he is independent, in some degree, of changes of weather, as it forms a sure defence against rain, should that overtake him in the midst of his operations. We are happy to be able to say, that the rick-cloth has been used in some parts of Scotland for several years past.

1177. Fig. 444 is a representation of a hay-stack in progress of erection, with the rick-cloth pitched over it, exhibiting the mode in which this cover is applied, and which may be described as follows.

Fig. 444.



THE MODE OF ERECTING A RICK-CLOTH OVER THE SITE OF A HAY-STACK WHEN IT IS BUILDING.

1178. Two light poles or spars of a length that will rise 10 or 12 feet above the intended height of the stack, are placed one at each end, and about 2 or 3 feet distant from the ends of the stack; these are supported by three guy-ropes, two of which, *c c*, fig. 444, stand opposite to each other, and the third *b* in the direction of the length of the stack, the ends being all secured to wooden stakes, and the fourth guy *a a* is common to both poles, extending from the head of the one to that of the other. A third spar, equal in length to the distance between the poles, is laid down either on the ground, if the stack is not yet begun, or in that portion of it that has been laid down; and the two tackles *d d*, being previously appended to the head of the respective poles, are hooked below to the third pole, which is to form the ridge of the cover. The canvass covering, or rick-cloth *e*, is now laid over the ridge-pole, with its middle bearing on the ridge-pole, and, if necessary, lashed thereto. The pole and cover are then hoisted up to any desired height, forming a temporary but safe and water-tight roof to the stack while it is being completed. The lower edges of the cloth are secured by bracing lines *f* to the sides of the stack, or they may be stretched out beyond these by means of the lines, and attached to stakes or otherwise, after which, as the stack rises, another pull is made upon the tackles, hoisting up the cover to afford sufficient space under it for the stack-builders.

1179. The figure represents one man in the act of forking hay from the cart upon the stack, and another adjusting the hay with a fork over its surface.

1180. Rick-cloths of all descriptions and sizes are manufactured by Mr Benjamin Edgington, 2 Duke Street, Southwark, London Bridge, London.

1181. SECTION SECOND—*Corn-reaping Machines.*—The process of reaping the crop in the season of harvest is the most engrossing event of the agricultural year, and that in which all the other operations of the farm may be said to centre. It is not surprising, therefore, that, from the earliest periods in the history of agriculture, there have been, from time to time, attempts made to facilitate the operation of harvest by the aid of machinery, more or less complex, for cutting down the cereal and leguminous crops. But it is a fact, not less curious than unaccountable, that this operation of reaping, simple though it may appear, continues to be almost entirely performed by the sickle and the scythe. Reaping by machine, doubtless, is now gradually extending, and considerable efficiency has been secured; but the attainment of a completely effective reaping-machine is an object yet to be sought for. Previously to entering into the description of the machines which have the highest reputation, it will be appropriate to take a retrospect of the progress of machine-reaping during the past half-century.

1182. Previous to the commencement of the present century, there had, even from the period of the Roman greatness, been occasional attempts at the accomplishment of a process by which the grain crops might be more expeditiously cut down than by the sickle; but none, it would appear, had ever assumed such a satisfactory form as to induce agriculturists to adopt them. Of the structure of such abortive attempts at a reaping-machine, little information has come down to us, and that little is vague and unsatisfactory. Nor is it of much importance that we are not in possession of direct information respecting them, seeing that nothing effective had ever arisen out of their attempts.

1183. Soon after the commencement of the present century, when agricultural improvements were making progress in every direction, by the extension of the use of improved machinery to the various branches of the art, the important department of the harvest operation naturally occupied a share of the inquiries then going on. Agricultural societies, too, by the offer of premiums, called forth the energies of inventors, both amateur and practical, in this particular line.

1184. *Boyce's Reaping-Machine.*—Very early in the century we learn of Boyce's reaping-machine, for which he secured a patent. This was based on the revolving-cutter principle; but the revolver was armed with a series of short scythes, which cut the corn as the machine moved along. It was destitute, however, of a proper apparatus for gathering and depositing the corn after being cut, and hence it never reached any degree of success.

1185. *Plunket's Reaping-Machine.*—About the same period, one Plunket, a London implement-maker, made a similar attempt, also on the revolving principle; but in place of the scythe of Boyce, he adopted a circular cutter, toothed like a fine saw or sickle. Being destitute, also, of a proper gathering apparatus, this machine acquired no reputation, and speedily was laid aside.

1186. *Gladstone's Reaping-Machine.* — Nearly about the same time, 1806, Gladstone, a millwright, of Castle-Douglas, Kirkcudbrightshire, brought out a reaping-machine that excited much interest, and possessed considerable promise. Its principle was the revolving circular smooth-edged cutter, supported in a carriage-frame, with two main-wheels only. A pair of long horse-shafts projected forward at one side, so that the horse walked alongside the standing corn—thus *drawing* the machine. The circular cutter was ingeniously overlapped by a sort of shield, armed with pointed prongs, projecting in front of the cutter, which served to collect and to hold the straw until the cutter had done its work. A complicated and peculiar apparatus was applied as a gatherer, to collect and deliver the cut corn in small parcels like handfuls. This machine, as given in the *Farmer's*

Magazine, vol. vii., appears to have possessed great ingenuity of contrivance as a whole. Its cutter also appears to have been formed on a sound principle; and it was, besides, provided with an apparatus by which the cutting edge could be whetted as often as necessary without stopping the action of the machine. Its gathering apparatus, however, carries too conclusive evidence that upon that member of the construction the whole design had failed, and the machine sank into oblivion like its predecessors.

1187. *Salmon's Reaping-Machine.*—At a still later period Mr Salmon of Woburn brought out a reaping-machine, under promising circumstances. In this there appears the first indications of a cutter on the clipping principle, combined with an apparatus for collecting and delivering, that promised to lay the cut corn in parcels like sheaves ready for binding. Although this invention seems to have been brought out under the most flattering hopes of success, it does not appear to have ever obtained the approbation of the class for whose use it was intended, and has been, like its precursors, almost forgotten.

1188. *Scott's Reaping-Machine.*—We may advert to one or two others in their proper order of date: of these the first is that of Mr Scott of Ormiston, East-Lothian, factor to the Earl of Hopetoun, an amateur mechanician of no small merit. During the war, in the early part of the century, he had directed his mechanical views to the construction of self-acting floating-machines or vessels for the purpose of disabling or destroying the fleets or ships of the enemy by stratagem. With the peace of 1815 he found that "occupation gone," and very adroitly turned his talent towards more peaceful objects. Amongst these came his reaping-machine, which, like most others, as we well remember, was an object of considerable interest for a time, although it ended in a failure, like those that had gone before. Mr Scott's machine had a cutter acting on the revolving principle, though not a circular cutter, but a wheel carrying sixteen small-toothed sickles, and had projecting prongs in front of them, like Gladstone's. He had copied Mr Smith's imperfect gatherer (an inverted conical drum), but added to it twenty-four jointed prongs or fingers, acting in the form of collectors or rakes, which were expected to convey the cut corn from the cutter to the ground. This machine was supplied with other contrivances, such as a brush to keep the cutters free of stubble or weeds, which might otherwise have stopped their proper action; but with all these precautions and auxiliary appendages, it is known that the machine never performed beyond a mere trial.

1189. *Ogle and Brown's Reaping-Machine.*—About 1822, Mr Ogle, at Renington, near Alnwick, invented a machine, by which he and a Mr Brown of Alnwick engaged to combine every act of reaping, except binding and placing the sheaves in stook. This machine is reported to have performed very satisfactorily in the field upon wheat and upon barley; but in consequence of no encouragement being given to the makers, the manufacture of the machine was dropt after the first complete specimen was made. The inventor, in 1826, published a drawing and description of the machine in the *Mechanics' Magazine*, vol. v., from which the following abstract is taken. The framework or body of the machine closely resembled a skeleton of a common cart, with its wheels and shafts, to the latter of which the horses were yoked to *draw* the machine, walking by the side of the standing corn. To the right of the carriage was projected the cutting apparatus—a light frame, whose front bar was of iron, and armed with a row of teeth 3 inches long, projecting forward; immediately upon these teeth lay the cutter, a straight-edged steel knife, equal in length to, and a little more than the breadth of the corn to be cut at one passage. By a motion from the carriage-wheels, this knife was made to vibrate rapidly from right and left, as the machine travelled.

Above, and a little before the cutter, a fan or vane was, from the same source, made to revolve, which thus collected and held the corn to be cut by the knife; and, on being cut, was by the vane carried backward, and laid upon a deal platform immediately behind the cutter: here, by the assistance of a man with a rake, it was collected to the extent of a sheaf, and then discharged.

1190. There is here observable a very curious coincidence in the almost perfect sameness, in every point, between Ogle and Brown's machine and one of the American reapers, Mr M'Cormick's, to be afterwards noticed; the similarity is so perfect, that the description of either would suit equally well for the other. But the curiosity of it is lessened from the consideration that similar coincidences are not uncommon amongst mechanists.

1191. *Kerr's Model of a Reaping-Machine.* — A case of this kind actually occurred at the period of Mr Smith's invention of his reaping-machine, in Mr A. Kerr, of Edinburgh, having produced a small model proposed as a reaper, in which the *cutter* and *gatherer* were exactly on the same principle as those of Mr Smith, and were admitted to be so by that gentleman. Kerr's model exhibits these two members precisely as admitted; and placed within them is a pair of small wheels, which are all that appears for a first mover. That such wheels could ever have served the purpose of impelling the action of a reaping-machine seems altogether improbable, though very applicable as an auxiliary to support the cutter at a proper height. To this defect it is easy to ascribe the failure of Kerr's machine, when extended to a working size.

1192. It were easy to multiply the competitors in this field of invention. At the periods above spoken of, the aspirants were numerous; but, with the exception of the four principal reaping-machines, yet to be noticed, none seem to have proceeded much beyond the formation of an imperfect model.

1193. Mr Smith of Deanston, afterwards so well known as an agriculturist, came on the field with his reaping-machine in the year 1812 with very considerable promise of success. Mr Smith, having been well trained as a mechanician, and being conversant in all the mechanical inventions and applications of machinery of the period to various manufacturing purposes, and having, of course, observed the numerous and successful applications of rotatory motion in preference to any kind of reciprocating action, wherever the former could be applied, was very naturally led to the adoption of the continuous rotatory action in the construction of a reaping-machine. This principle he accordingly did adopt, and, although his first trials were not altogether successful, they were such as led to a series of improvements that brought the machine, as we shall see, to a degree of efficiency which promised ultimate success. The Dalkeith Farming Society had previously offered a handsome premium for the invention of an effective reaping-machine, and Mr Smith became the only competitor in 1812. In the following year the machine, in its improved state, was again exhibited in operation before a committee of the Dalkeith Club, when they, although not considering it entitled to the full premium, voted to Mr Smith a piece of plate, value fifty guineas; and shortly after, the Highland and Agricultural Society having appointed a committee to examine and report on its efficiency, found that report so satisfactory that a piece of plate of fifty guineas' value was in like manner voted to the inventor, and at the same time a complete model of the machine was lodged by Mr Smith in the Society's Museum, which is now transferred to the Technological Museum.

1194. *Smith's Original Reaping-Machine.*—In its original form, this machine consisted of a horizontal wooden frame of about 7½ feet long and 3 feet wide. Beneath this was attached the main axle and pair of broad wheels, of about 5 feet in height, the axle turning with the wheels by means of spring and ratchet, and carrying a spur-wheel, which geared into another fixed upon a shaft placed above the wooden frame, and parallel to the main axle, and thus gave motion to the succeeding movements of the machine. This last shaft carried a pair of reversed bevel-wheels, loose on their shaft, while they continued both in contact with a third wheel fixed on a shaft, placed horizontally above the frame; a sliding-clutch on the former shaft brought either of the two bevel-wheels, at the pleasure of the conductor, into action with that upon the horizontal shaft, by which arrangement that shaft was turned to the right or to the left, or by placing the clutch so that neither was in contact with it—the third wheel and its shaft remaining stationary. On the forward end of the horizontal shaft was placed another bevel-wheel acting upon the pinion of an upright spindle; and this spindle, supported on the forward extremity of the horizontal frame, assisted by a three-ribbed iron arch raised above the frame, was, by means of the two bearings, kept sufficiently steady for its duty of carrying the circular cutter at its lower extremity. Here, however, the spindle had a further support from a pair of small wheels and frame, placed under the foot of the spindle, and by a stay of iron proceeding from the hinder part of the frame. The cutter, 5½ feet in diameter, was composed of thin steel segments bolted upon an iron ring, and this last was surmounted by an inverted frustum of a cone, formed of sheet-iron, whose lower diameter was 10 inches less than the cutter, or 4 feet 8 inches, while its diameter at top was 5 feet 4 inches. The front wheels under the cutter were only 14 inches diameter, and about as much apart; their duty was to keep the cutter at the regular distance from the ground to which it might be set for the time being. The gearing above described was so arranged as to bring out a velocity in the edge of the cutter, such that, for every inch of progressive motion of the whole machine, any point in the edge of the cutter passed through a space of 9 inches in its motion of revolution. The machine was moved by two horses yoked to a pole fixed to the wooden frame, and projecting from behind, so that the horses pushed the machine before them by drawing with trace-chains from a yoke-bar attached to the end of the pole behind them. By means of the clutch and bevel-wheels the cutter could be made to revolve to right or left, and the cut corn laid down right or left accordingly; convenient means were also provided for placing the cutter higher or lower at pleasure, by means of a lever that lifted or lowered the cutter and conical drum, acted upon by a chain and screw, the latter brought to a convenient point at the end of the pole. In working, the grain was cut regularly and well. The drum revolving with the cutter carried the cut corn round until it fell off at the side of the machine in a pretty regular continuous swathe.

1195. *Smith's Improved Reaping-Machine.*—The description here given applies to Smith's machine, after it had undergone some improvements up to 1814; from that period, at occasional intervals, it was brought out with renewed hopes of success, until, in 1835, at the Highland and Agricultural Society's Show at Ayr, it was exhibited in operation with remarkable *eclat*. Mr Smith had now engrafted upon it an important addition, borrowed from a machine which has yet to be described, invented by Mr Mann, Raby, Cumberland. This was the attachment of a series of rakes placed vertically upon the periphery of the original drum, the teeth of the rakes being about 6 inches long. This served the purpose of a more certain conveyance of the cut corn to the place of delivery at either side of the machine. Although the application of the rakes was less efficiently done than in the machine from which the idea was taken, their velocity being here the same as that of the cutter, they nevertheless seemed to facilitate the process of gathering, which hitherto had been imperfect. The experiment was made on a field of wheat in a fair condition for being cut by a machine. The operation began, not at an outside, as was usual, but right in the middle of the field, the spectators being placed around the point of commencement; and amongst these we had the fortune to be placed. The passage of the machine through the field left behind it an open lane, where nothing was at first observable but a bare stubble, the cut corn being all laid down at one side against the standing. Never, perhaps, did an experiment come off with better effect or greater success; the general impression was that the problem had at last been solved—that Smith's machine was complete. Not so was it, however, in fact; for, notwithstanding the striking effects produced by that day's trial, the machine remained, and to this day remains, without making further progress.

1196. It is more than probable that the failure of this machine rested mainly on the following defective points—1st, From its great length and weight it was unwieldy in all its movements; 2d, From its great length, also, and from the mode of attachment of the horses, together with the want of a swivel-carriage either before or behind, it was defective in turning at a landing; 3d, From the small diameter of the bearing front wheels, and especially from these being placed nearly directly under the centre of the revolving cutter, this important member, when these wheels fell into a furrow, ran right into the brow of the adjacent ridge, and thus destroyed for the time its whole edge, its projection before the wheels being nearly 2½ feet; and 4th, It may be stated as an objection, that the price could not be much under £50.

1197. *Mann's Reaping-Machine.*—The next important step in this direction was taken by Mr Joseph Mann, Raby, Cumberland, who brought out a reaping-machine in 1820, in the state of a working model, before the Abbey Holme Agricultural Society, who expressed their approbation of the design, and advised a horse-power machine to be constructed with some proposed alterations, one of which was that the horses should *push* instead of *draw* the machine, the model having been upon the drawing principle. These alterations seemed to have turned out rather unsuccessful, for in 1822 a full-size machine was exhibited to the same society; but the mechanist having endeavoured to satisfy too many opinions, his machine became so complicated that its success was doubtful, and it fell aside till 1826, when Mr Mann returned to his favourite method of *drawing* instead of pushing; and from this period to 1830 he was, from time to time, engaged in completing his improved design, which, from his own statement, at last possessed four principal points of a good reaping-machine: 1st, It preserved the parallelism of the line of draught, though that draught was applied to one of its angles in front; 2d, A polygonal cutter; 3d, The gathering process from the cutter, performed by a revolving series of rakes; and, 4th, The process of stripping the rakes in such manner as to lay down the cut corn in a regular swathe by the side of the machine as it progressed.

1198. Mr Mann's machine, possessing the above-described points, was exhibited at the Highland and Agricultural Society's Show, held at Kelso in 1832. On this occasion we had ample opportunity of studying its construction, and also witnessed its trial on a small portion of a field of oats, performed under very unfavourable circumstances. The portion of the field acted upon had been later than the other parts, hence it was left uncut, and still unripened, and withal thought so worthless that cattle had been allowed to traverse it. But notwithstanding all this, the machine performed the operation of cutting much better than could have been expected under the circumstances, while the laying of the cut corn in the swathe was performed very regularly. In working up-hill, and especially in crossing the ridges, its operation was less satisfactory; and on the whole, although the trial called forth much approbation, the judges could not take upon them to recommend a premium. Nevertheless, it must be admitted that, making allowance for Mr Mann being only an amateur mechanic, and having constructed the machine almost entirely by his own hands, it could not be expected to be other than a rude specimen of mechanism, and, therefore, not capable of doing all that the principles involved ought to have brought out: it deserves, however, to be looked upon as possessing the germs, at least, of the *four points* which its author held to be the ultimatum sought for in a reaping-machine. It is still our opinion also, in looking back, that the principles of that machine, in the hands of an able mechanician possessed of capital (for of that commodity, like many others of his kind, the inventor was deficient), might have placed it foremost in the competition for the solution of the problem.

1199. As it may be interesting to those who may yet turn their attention to the construction of the reaping-machine, the following description is given from the writer's original paper, published with drawings in the *Journal of Agriculture*, which for more minute details may be consulted by the machinist.* In Mann's machine, the cutting process is performed on the revolving principle; but instead of a circular cutter like Smith's, one of a polygonal form had been preferred, having twelve equal sides. By this form of cutter the action upon the standing corn is somewhat different from that of the perfectly circular cutter: with the circular cutter the cutting edge is constantly and equally acting upon the standing corn, but with the polygonal the effect is a rapid succession of strokes, arising from the inclination of the cutting edges in the sides of the polygon to each other; for, as will readily be understood, from the angles of the polygon being farther from the centre of revolution than any point in the straight side thereof, any opposing body, as a stalk of corn, will be forcibly acted upon when the angle is passing the stalk; and, if passing without completing the separation, the progressive motion of the whole machine will not only keep the edge in contact through the first half of the passing side of the polygonal edge, but as the next angle approaches the stalk, it will receive the more impressive stroke from the remaining half side to complete the severance—and so of all the rest.

1200. The cutter is formed in twelve separate segments of thin steel plate, fixed upon the extremities of a corresponding number of horizontal arms attached to a vertical revolving shaft. The joinings are formed by the ends of the segments lapping over each other, and situate posteriorly to the angles of the polygon in relation to its motion of revolution. The segments of the cutter were attached to the revolving arms by means of a slender slide-bar of iron, riveted on to each end of the segment; and these sliders, two together, being those of the contiguous ends of two segments, were passed through a clasp in the ends of the arms and there secured by a pinching-screw. This mode of attaching the cutter rendered the removal for sharpening extremely convenient, as a whole spare set of the segments could be carried with the machine, the change of the one set for the other being capable of accomplishment in a few minutes. The cutter, when completed with all its segments, was 4½ feet diameter; and taking the rate of progressive motion at 2½ miles per hour, the

* *Journal of Agriculture*, vol. i. p. 250.

cutters made 175 revolutions per minute, which corresponds very nearly with the rate in Mr Smith's machine.

1201. The framework of Mann's reaper was of rather irregular construction: in plan its form was that of a trapezium, the sides parallel, the back at right angles to them, and the front side had the acute angle at the left or nigh side, and to that the draught was applied by means of a pair of horse-shafts. This framework was supported on three principal wheels: of these, two had a diameter of 3 feet, one being on each side towards the rear, but that on the off-side about a foot in advance of the other, and from the axle of it alone the movements of the working parts were derived. The third wheel had a diameter of 2 feet, and was attached to an upright, or rather a sloping swivel-shaft, placed in connection with the acute angle of the framework, and to which the horse-shafts were firmly attached—making thus to the machine a swivel or fore-carriage, by which it could be directed or turned round in a small space. A fourth and much smaller wheel or roller worked in the fore-end of the perch that extended from the lower part of the framework, and on which rested the foot of the cutter-shaft directly over this fourth wheel; but of its utility there are doubts.

1202. One of the peculiarities of this reaper was the application of the revolving rakes to gather the corn as it fell from the cutter. This was accomplished by the construction of a skeleton cylinder, placed over and revolving concentrically with the cutter upon the upright shaft of the latter, but independently of it, and with a different velocity. The cylinder was mounted with 25 rakes attached to it in a vertical position, each rake having 10 teeth of about 6 inches long. The revolutions of the rake-cylinder were made in the same direction as the cutter, but at a rate only as one to seven of the latter—namely, about 28 per minute. To complete the gathering part of the process, a second and fixed rake or comb was attached in a vertical position to the near side of the framework. The wooden teeth or prongs of this comb were of considerable length, and were projected horizontally between the lines of teeth in the revolving rakes. In the latter, also, a ring of light wire was carried round each row of the teeth horizontally, having an attachment to every tooth about 2 inches from its root; and as the point of the prongs of the comb lay within or nearer to the centre of revolution than those rings of wire, not a single straw could escape the comb, but every straw was regularly stript from off the rakes as it came round. The cut and gathered corn was thus regularly laid down in a continuous swathe, the stalks of grain lying parallel to each other, and nearly at right angles to the line of progress of the machine.

1203. The gearing of this machine was extremely simple. On the axle of the off-side carriage-wheel, already alluded to, was fixed a bevel-wheel of 56 teeth, which acted on a horizontal wheel of 28 teeth; and upon the vertical shaft of this last were mounted two pitch or chain wheels, the one of 8 teeth, the other of 28; these, by means of two pitch chains, acted upon two other wheels of 21 and 9 teeth respectively, placed upon the rake-cylinder and upon the cutter-shaft, bringing out the velocities before named for the two members. Besides these active motions, there was provision by means of levers, by which the height of the stubble could be regulated almost instantaneously, and the revolving parts thrown out of gear, and also for raising or depressing either side of the machine to suit the rounding of ridges and deep furrows.

1204. The power required to draw this reaper was one horse, and with this it cut down a breadth of 3 feet; so, taking its rate of travel at 2½ miles per hour, its performance, by calculation, is limited to 9 acres in 10 hours, or thereby; but in actual work it might not exceed 7 acres in that time.

1205. Of all the reapers hitherto taken notice of in this work, it is believed that not one of them was ever worked throughout a harvest. Even Smith's and Mann's machines, which were the most perfect, do not appear to have been worked beyond a few hours consecutively; their actual capabilities, therefore, seem never to have been properly tested.

1206. *Bell's Reaping-Machine.*—The year 1826 may be held as an era in the history of this machine, by the invention, and the perfecting as well, of a really effective mechanical reaper. This invention is due to the Rev. Patrick Bell, now minister of the parish of Carmylie in Forfarshire. The principle on which its cutting operation acts is that of a series of clipping shears. When the machine had been completed, Mr Bell brought it before the Highland and Agricultural Society, who appointed a committee of its members to inspect its operation in the field, and to report. The trials and the report being favourable, the Society awarded the sum of £50 to Mr Bell for his invention, and a correct working-model of the machine was subsequently placed in the Society's Museum. The invention shortly worked its way to a considerable extent in Forfarshire; and in the harvest of 1834, we, in a short tour through that county, saw several of these machines in operation, which did their work in a very satisfactory manner. Dundee appears to have been the principal seat of their manufacture, and from thence they were sent to various parts of the country. It is known, also, that *four* of the machines were sent to the United States of America; and this circumstance renders it highly probable that they became the models from which the numerous so-called inventions of the American reapers have since sprung. At the great fair or exhibition held at New York in 1851, not fewer than six reapers were exhibited, all by different hands, and each claiming to be a special invention; yet, in all of them, the principal feature—the *cutting* apparatus—bears the strongest evidence of having been copied from Bell's machine.

1207. To enable our readers to form a just conception of the construction and principles of Bell's machine, and to compare it with those now being introduced after the American copy, a plate is given, showing a full view, in perspective, of Bell's reaper in its most genuine form. The machine consists, first, of an open carriage-framework of carpentry about 4 feet wide, the same in length, and about 3 feet high, marked *a a* in fig. 1, Plate XX. This is supported on two principal wheels *b b*, about 4 feet in diameter, and two minor wheels *c c*, 18 inches in diameter, supporting the fore-part of the carriage, to the front bar of which the cutting apparatus is attached. The axle of the main wheels *b b* passes quite through the carriage-frame, and supports it by turning in bearings fixed to the middle horizontal bars, on either side. On this axle is fixed a bevel-wheel *e*, 20 inches in diameter, turning with the main wheels and axle, and gearing into the bevel-pinion *f*, fixed upon the sloping shaft *g*, which, at its lower end, carries a short crank *h*. This last, by means of the connecting-rod *i*, gives the vibrating motion to the cutter-tail bar *k*, to which bar the tails of the movable blades of the series of shears are loosely jointed.

1208. The bevel-wheel *e* gives motion also to the small sloping shaft *l*, through a pinion not seen in the figure; and at the upper end of this shaft, by means of the two small mitre-wheels *m*, motion is given to a small horizontal shaft *p*, on the end of which a combination of three bevel-wheels and clutch at *q* gives motion to the first web-roller, making the web *o* (which is here represented as torn off to expose the parts below) revolve to right or left, as desired. The web *o*, when in action, is stretched over the two rollers *n n*. The light iron bars *v v* serve to carry the revolving fly *w* or vane to collect and carry the cut corn to the web.

The vane *w* derives its motion from a pulley fixed on the extreme end of the small shaft *p*, another, *x*, being fixed on the extremity of the axle of the vane *w*; and a small band passing round these pulleys completes the motion. The vane *w* is readily adjustable upon the light arms *v v*, to suit any height of grain, and also in distance horizontally, to suit the delivery of the cut grain upon the web *o*.

1209. This machine is worked by two horses, pushing it before them by means of the pole *s*, to which they are yoked by the common draught-bars, fig. 288.

1210. In its original form, a castor or swivel-wheel was attached under the machine, and brought to bear up the hind-part of it from the ground, by a rack and pinion worked by a handle. The intention of this was to obviate a supposed difficulty in turning the machine. Experience, however, has shown that the supposition was groundless. The swivel-wheel has been laid aside; and as one of the main wheels necessarily required the convenience of being disengaged from the gearing that drives the cutter, &c., the same disengagement serves to make the machine turn with all requisite facility.

1211. The cutter consists of a fixed bar of iron *r r*, 6 feet in length, so that it projects over and clears a passage for all the bearing wheels and other projecting points in the machine. The bar is strongly attached to the fore-part of the framework by two iron brackets, and to the bar are firmly bolted the 13 fixed blades of the shears. The 12 movable blades are likewise attached to the same bar, each upon a joint-bolt. Each of these last blades is prolonged backward in a tail-piece, till they rest in the vibrating bar *k*, where the extremity of each tail rests between two pegs, which serve as a secure but simple and loose joint for it.

1212. Such are the different motions of the machine, and, when in operation, the effects are as follows: The driving-wheels *b b* being nearly 4 feet in diameter, one turn of these carries the machine in its progressive motion over 12 feet of surface. The bevelled-wheel and pinion *e* and *f* being in the proportion of 6 to 1, the crank and cutter-tail bar *k* will make six vibrations in the time that the machine moves over 12 feet; but as the movable blades of the shears cut both ways, they will each make 12 cuts in the same time, each cut extending to 12 inches forward; and as the cutting-blades are 14 inches long, the uncut corn can never reach the *root* or joint-end of the shears, to produce choking. The revolving vane *w* in front serves to catch hold of and retain the corn against the onward pressure of the cutter, but their chief duty is to assist in laying the cut corn upon the endless web *o*. The duties of the web are very simple, being merely to convey the cut corn to right or left, and to deliver it upon the ground, which it does with a regularity perfectly sufficient for the purpose of being gathered into sheaves.

1213. In the process of working this machine, Mr Bell's practice is to employ one man driving and conducting the machine; eight women are required to collect the cut corn into sheaves, and to make bands for these sheaves; four men to bind the sheaves, and two men to set the sheaves up in stooks—being in all fourteen labourers, besides the driver of the horses, whose time reckons along with them; and the work performed averages 12 imperial acres per day. These data have been obtained from fourteen years' experience of the machine, and have therefore a strong claim upon the consideration of the farmer.

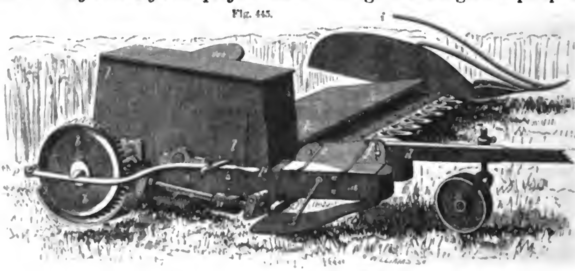
1214. The expense in money for reaping by such a machine will, of course, vary a little with the rate of wages; but, on an average, it may be taken at 3s. 6d. an acre, including the expense of food to the workers. This, in round numbers, may be taken at a saving of one-half the usual expense of reaping by hand, at the lowest calculation; and the saving on a farm where there might be 100 acres of cereal and leguminous crop would do more than cover the price of a machine of the best quality in two years.

1215. It is difficult to account for the reason why Bell's machine has not been more extensively adopted. For a period of nearly twenty years it was successfully used; and yet it seems doubtful whether, with practical agriculturists, it has so high a reputation as its American rivals—the machines of Hussey and M'Cormick—yet to be described. "There have always," says the Report of the Royal Agricultural Society, on the exhibition and trial of implements at Chelmsford (1856), "been some points of excellence in Bell's machine not shared by any other. The power of cutting in any direction, of delivering the corn on either side, right or left, and of requiring no scytheman to prepare its way, are advantages peculiar to this machine. These have hitherto been considered as counterbalanced by the excessive draught of the machine, by the liability of the delivery-web to become disordered, and by the labour and difficulty of steerage. These drawbacks have, since last year, been in a considerable degree removed. The delivery-web has been superseded by three gutta-percha bands, which, without deducting from its former efficient delivery, has reduced friction and greatly diminished draught. Other minor alterations have been made, still further diminishing draught." The improvements here alluded to have been introduced by Mr Crosskill, the well-known agricultural engineer of Beverley, in Yorkshire. It is but right, however, to state that these modifications on the original plan have been introduced without the sanction or approval, we believe, of the inventor, the Rev. Patrick Bell.

1216. It now remains for us to describe the two machines which have been most prominently before the public during the last few years—these being known as Hussey's and M'Cormick's—Hussey's being manufactured by Messrs Dray & Co., engineers, of Swan Lane, London Bridge, London; M'Cormick's by Messrs Burgess and Key, Newgate Street, London. These firms have introduced great improvements in the machines which they respectively manufacture; so much so, that there would be some difficulty in recognising in them the same machines, the appearance of which, at the Great Exhibition of 1851, created such an interest in the agricultural world. It is not now necessary for us to describe and illustrate their early forms, so as to show the progressive improvements which have been effected on them; their present condition of comparative efficiency, to which they have attained, by the exercise of much patience and considerable skill by the parties who make them, being of greater interest to the agriculturist.

1217. *Dray's Hussey's Reaping-Machine.*—In fig. 445 we give a perspective

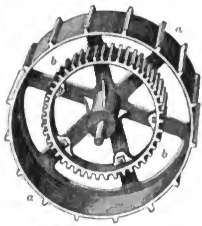
Fig. 445.



DRAY'S HUSSEY'S REAPING MACHINE IN PERSPECTIVE.

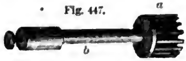
view of Hussey's reaper, improved by Messrs Dray. The side-beams *a a* of the gearing-framing are 6 feet long, 4 inches thick by 6 inches deep; they are kept 10 inches apart by two cross pieces or binders. The main driving-wheel *a a*, fig. 446, is 2 feet 8 inches diameter, 7 inches broad on the periphery or ring, and is provided with a series of ribs ½ inch deep, placed transversely across its periphery—these enabling the wheel, when travelling, to take a firm hold of the ground. The shaft of this wheel revolves in bearings, one of which is placed in each of the side-beams *a a*, fig. 445. To the interior arms of the wheel *a a*, fig. 446, a spur-wheel *b b*, 18 inches in diameter, is attached. This engages with a pinion *a*, fig. 447, keyed on to the shaft *b*, which carries the large bevel-wheel *b b*, fig. 445; the shaft of this revolving in bearings bolted on to the left-hand beam *a a*. This bevel-wheel *b b* engages with a pinion *a*, fig. 448, keyed on the end of the crank-shaft *b*, which revolves in bearings shown in the figures with their attached bolts, by means of which they are bolted on to the left-hand beam *a a*, fig. 445. The connecting-rod *a b c*, fig. 449, is jointed at one end *a* to the pin *d* of the crank-shaft, fig. 448, and at the other end, *c*, to the joint *a* at the end of the bar *a b*, fig. 450, which carries the cutter-blades *c c c*. The length of the connecting-rod *a b c*, fig. 449, is 17½ inches from centre to centre. The cutters *c c c*, as they reciprocate to and fro, play in the slots of the projecting fingers *c c*, fig. 445. The form and size of the cutter-blades and of the fingers

Fig. 446.



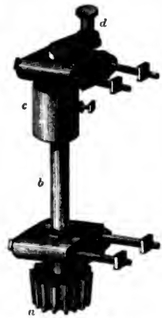
DRIVING-WHEEL AND GEAR OF DRAY'S REAPER.

Fig. 447.



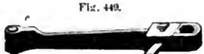
DRIVING-PINION AND SHAFT OF DRAY'S REAPER.

Fig. 448.



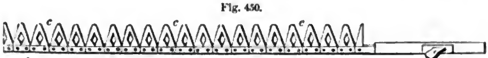
CRANK-SHAFT FOR DRIVING CUTTER-BLADE.

Fig. 449.



CONNECTING-ROD OF CUTTER-BLADE.

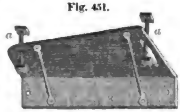
Fig. 450.



CUTTER-BLADE.

will be hereafter described. The draught-pole *d d*, fig. 455, is bolted to the pole-plate *e f*, and in fig. 451, by two bolts, one of which is fixed in the end of the pole-plate nearest the driving-wheel, and the other moves in a curved slot *f* at the opposite end of the pole-plate *e f*. This allows of the vertical adjustment of the pole *d d*. The height at which the cutters work from the ground is regulated by two wheels, the first of these being connected to the framing opposite to that at which the driving-wheel is placed; the second of the adjusting-wheels, *h h*, is attached to the pole *d d*. The first-named wheel *a*, fig. 452, is hung at the centre of the bar or lever *c d*, jointed at its end *c* to the side-framing, and provided with a curved guide *d* and handle *e* at the other extremity. A bolt is fixed to the side-framing, and passes through

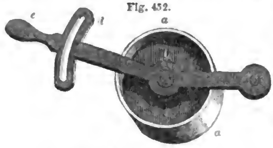
Fig. 451.



POLE-PLATE OF DRAY'S REAPER.

the slot of the curved guide *d*, fig. 452. By pressing downwards on the handle

Fig. 452.



GUIDE FOR ADJUSTING-WHEEL.

e, the curved guide *d* is depressed, and the central part *b* brought nearer to the ground, and the end of the machine and the cutter-bar lifted further from it. The guide *d* is fixed at the point required by screwing up the nut provided to the bolt passing through the slot of the guide. The stem or central bar, conveying the wheel *h h*, attached to the pole-plate *d d*, fig. 445, is movable in a vertical direction in the central aperture of a guide *a a*, fig. 453, bolted to the side of the pole-plate. A nut and screw on the spindle of the wheel *h h*, above

Fig. 453.

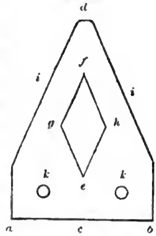
GUIDE FOR STEM OF ADJUSTING-WHEEL.

and below the guide, retain the spindle in any desired position in the guide aperture. The two wheels *a a*, fig. 452, and *h h*, fig. 445, are so adjusted as to make the cutter-bar level throughout its length. The following are the dimensions of the pole-plate *f f*, fig. 451: Extreme length 17½ inches, height at lower end 5 inches, at highest 8 inches. The distance of curved slot from end 1¼ inch, length of slot 4½ inches, breadth of slot ¾ inch. The pole-plate is strengthened by two diagonal stays of wrought-iron. The distance of the first stay from the highest end is 4½ inches, of the second at the lowest end 5 inches, the width of the stays being 1¼ inches. The plate by which the pole-plate is attached to the beam *a a*, fig. 445, is 3¾ inches at its narrowest, and 4 inches at its broadest part. The height of the cutter-bar can be adjusted by the wheels *a a*, fig. 452, and *h h*, fig. 445, at any point within a range of from 2 to 8 inches. To the side-frame carrying the wheel *a a*, fig. 452, the delivery finger *i i*, fig. 445, is attached. This goes in advance of the machine, and brings the grain within the action of the cutter-blades. The tilting platform *k k*, fig. 445, 2 feet 6 inches broad, and 4 feet 8 inches long, is made of light timber covered with zinc plates. It vibrates or oscillates on a central bar.

1218. On the machine being adjusted, so that the knives will leave a stubble of the height required, the gearing covered by the box *l l*, fig. 445, the pole *d d* inserted, the horses yoked thereto by whipple-trees, and all the parts well oiled, the attendant mounts the box *l l*, sitting on the part *m*, inserts his right foot in a loop formed by the strap attached to the corner of the tilting platform *k k*. On the machine progressing, the driving-wheel *a a*, fig. 446, revolves, and with it the spur-wheel *b b*, which engages the pinion *a* in the shaft *b*, fig. 447. This gives motion to the bevel-wheel *b b*, fig. 445, and through the pinion *a*, fig. 448, to the crank-shaft *b*, and connecting-rod *a b c*, fig. 449, and the cutter-bar *a b*, fig. 449. The cutter-blades have thus given to them a rapid reciprocatory movement in the slots of the fingers *c c*, fig. 445. The corn passing between these is cut, and falls back on the tilting platform *k k*. On the attendant deeming a sufficient quantity delivered to the platform, he raises his right foot, and this being attached by means of the strap to the front edge of the platform, it is tilted upwards, and the grain deposited behind. The operation of delivering the grain behind is also facilitated by a rake which the attendant wields. To prevent the jarring action of the cutter-blade, resulting from its rapid oscillation, a balance-weight *n*, fig. 445, is attached eccentrically to the crank-shaft *o*; this acting as a species of fly-wheel, bringing the crank *d*, fig. 448, easily round the "dead" points. The bevel-wheel *b b*, fig. 445, is thrown out of gear with the pinion on the end of the shaft *o* by means of the lever-handle *p p*, a part of which embraces a clutch on the extremity of the shaft carrying the wheel *b b*. This lever is within reach of the attendant sitting on the box. On the wheel *b b* being thrown out of gear with the pinion *a*, fig. 448, the motion of the knives or cutter-blades is stopped.

1219. Having described the general arrangements of this form of reaping-machine, we shall now illustrate several of its important details. And first of the cutter-blades and fingers. In fig. 450 we give a plan of the cutter-bar, the extreme length of which is 7 feet 2¾ inches, the thickness ¼ inch, and breadth 1 inch; it is strengthened by a part at the end *a*, 1 foot 8½ inches in length and 1½ inch in breadth, the united thickness being ½ an inch. To the centre of this part a stud *a* is riveted, one end of the connecting-rod *c*, fig. 449, being jointed to this by a pin or bolt of ¾ inch diameter. The length of the base of the stud *a* is 5¼ inches, its breadth 1½. The strengthened part of the cutter-blade *a*, fig. 450, slides in a guide, fixed to the under-framing, in a line with the crank. The knives *c c c*, fig. 450, of hardened steel, are riveted to the bar *a b* by two rivets of ¼ inch diameter; there are twenty-one knives, the end *b* of the bar being terminated by half a knife. In fig. 454 we give a plan of the knife one-third full size; the width from *a* to *b* is 3 inches, the extreme length from *c* to *d* 4¼ inches, the point *d* being rounded off to ⅜ths of an inch. A lozenge-shaped part is cut out of the centre, its length from *e* to *f* being 2¼ inches, its breadth from *g* to *h* 1 inch. This aperture prevents the blades choking while working in the slot of the fingers. The edges *i i* of the knife are bevelled off from the upper side to form cutting edges; *k k* are the rivet-holes for connecting the blade to the bar *a b*, fig. 445.

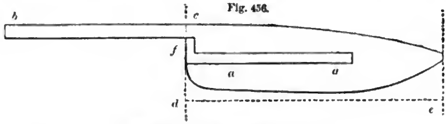
Fig. 454.



PLAN OF KNIFE OF DRAY'S REAPER—⅓ FULL SIZE.

1220. The fingers are riveted to a bar or finger-plate of wrought-iron 3 inches broad and 1½ inch thick, placed across the front of the machine. In fig. 455 we give a plan, and in fig. 456 a side elevation of a finger one-third of the full size. The extreme length from *a* to *b*, fig. 455, is 9¼ inches; the diameter from *c* to *d* 1⅜ inch; the distance from centre to centre of rivet-holes *e* and *f* 1¾ inch; diameter of rivet-holes, ⅜ths of an inch. The width from *g* to *h* is 1 inch, rounded off at *i k* to a width of ¾ths of an inch, which is the breadth of the projecting end of the top side of the finger *a l m*. In fig. 456, the slot *a a*, in which the knives work, is ¼ of an inch in depth. The thickness of the end of the finger where it is riveted to the finger-plate, as at *b c*, is ½ an inch; the length of the part from *d* to *e* is 5½ inches. From *b* to the side of the set-off *f* the length is 4⅜ inches; the depth of the set-off nearly 3 inches.

Fig. 456.



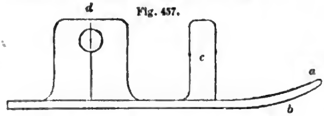
SIDE ELEVATION OF FINGER—⅓ FULL SIZE.

Fig. 455.

PLAN OF FINGER—⅓ FULL SIZE.

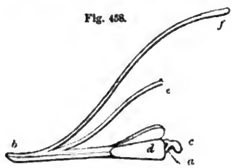
1221. In fig. 457 we give enlarged views of the shoe sustaining the delivery-finger *i i*, fig. 445. This is formed of plate-iron bolted to the under-side of the beam, which supports the wheel *a*, fig. 445; it is curved upwards, as shown in fig. 457 at *a b*. At a distance of 3 inches from the point *a*, a slotted guide *c* is fixed $2\frac{1}{4}$ inches in height and $\frac{3}{4}$ of an inch broad, the distance between the sides being $\frac{1}{2}$ an inch. At a distance from this of $3\frac{1}{4}$ inches, a stud *d* is attached, with a slot in the centre, $\frac{1}{2}$ an inch in width. A bolt-hole is made on each side of the stud *d* $\frac{3}{8}$ths of an inch in diameter. To the delivery-end *a*, fig. 458, of the finger *a b c*, is jointed a bolt $2\frac{1}{4}$ inches long and $\frac{3}{8}$ inch diameter, passing through the hole in the side of the stud *d* in fig. 457, and the bolt-hole of the eye *a* of the delivery-finger *a b c*, fig. 458. The bar *b a c*, being jointed at *a*, allows the point *b* to rise and overcome any obstacle which may be lying in its path while entering among the corn: as the bar rises and falls, it plays in the slot of the part *c*, fig. 457. The length of the central bar *b c*, fig. 458, is 2 feet 3 inches, 1 inch deep, and $\frac{3}{4}$ of an inch thick at its strongest section; the distance from the end *c* to the centre of the eye *a* is $3\frac{1}{4}$ inches. The eye is elliptical in form, $1\frac{3}{4}$ inch long, and same breadth, the diameter of the bolt-hole in its centre being $\frac{3}{4}$ of an inch. To the central bar *b c*, fig. 458, shields (one of which is shown at *d*, fig. 458) *a a*, fig. 459, are riveted at the point *b*; the extreme length of those is $11\frac{1}{4}$ inches; the width at broadest end $4\frac{1}{2}$ inches, narrowed at the point *b* to the depth of the bar. The shields are shown in plan in the lower part of fig. 459; the distance from point to point of the extended part *c c* being $3\frac{1}{4}$ inches. From the central bar *b c*, fig. 458, two light rods, *e* and *f*, curve upwards and outwards. The height to which the extremity of *e* rises, measured from the point *a*, is 1 foot 9 inches; the length of *b f* is longer than *b e* by $16\frac{1}{4}$ inches, and the distance between the rods *b f* and *b e*, at the extremity of *e*, is $8\frac{1}{2}$ inches.

Fig. 457.



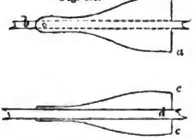
SIDE ELEVATION OF SHOE—SCALE IN FIG. 130.

Fig. 458.



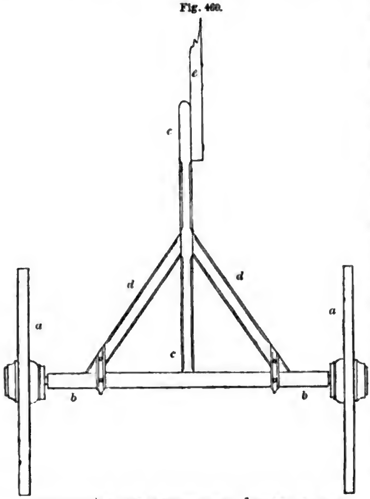
VIEW OF DELIVERY-FINGER.

Fig. 459.



SHIELD OF DELIVERY-FINGER—SCALE, 1 INCH TO THE FOOT

Fig. 460.



PLAN OF DRAY'S REAPER CARRIAGE—SCALE, ¾ INCH TO THE FOOT.

1222. In fig. 460 we give the plan of the carriage, to the under-side of which the reaping-machine just described is swung, for the purpose of easy conveyance from place to place.

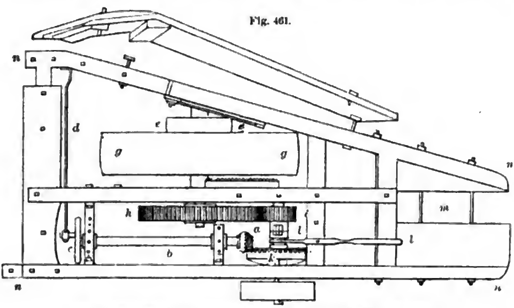
The wheels *a a* are 4 feet 10 inches diameter, and 3 inches tire; the axle-beam *b b* is 6 feet long and 4 inches broad, by 5½ inches deep. The central beam *c c* is 6 feet long and 3 inches broad by 5½ inches deep. The stays *d d* are 2½ inches broad by 5½ inches deep. Part of the reaper-pole is shown at *e*.

1223. The price of Dray's Hussey's reaping-machine is £25.

1224. *M'Cormick's Reaping-Machine.*—We shall now describe M'Cormick's Reaper, with the improvements introduced by Messrs Burgess and Key, Newgate Street, London. While the cutting apparatus and driving-gear of this machine present features somewhat similar to those of Hussey's machine just described, there is an essential difference in the mode of delivery. While in Dray's, the grain, after being cut, is delivered to a platform, the working of which requires a special attendant, and the grain, delivered to the ground in quantities sufficient to make a sheaf, is required to be immediately bound up in order to clear the path for the return journey of the machine—in Burgess and Key's, the cut grain is at once delivered to a screw platform, and passed to the ground at the side of the machine. A special attendant is therefore not required, and the grain, moreover, being delivered at the side, may be left till the whole can be conveniently bound up.

1225. In fig. 2, Plate XX., we give a perspective view of this machine, *a a* the main framing, carrying the driving-wheel *b b*, on the shaft of which is the spur-wheel *c*, engaging with the pinion *d*, keyed on the shaft of the bevel-wheel *e*. This engages with a bevel pinion *a* in fig. 461, keyed on the end of the

Fig. 461.



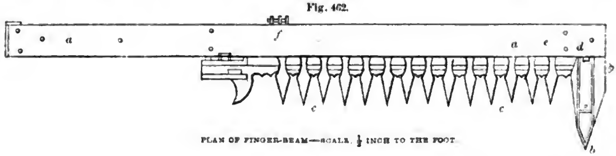
PLAN OF GEARING OF M'CORMICK'S REAPER—SCALE, ½ INCH TO THE FOOT.

crank-shaft *b*, which works the cutter-knives through the medium of the crank *c* and connecting-rod *d*. On the shaft carrying the main driving-wheel *b b*, fig. 2, Plate XX., a pulley *e e*, fig. 461, is keyed; this carries a driving-belt *f*, which passes over a pulley *g*, fig. 2, Plate XX., on the shaft of the gathering-reel *h h h*. The office of this reel is to bring the grain to the action of the cutter-knives, this being aided also by the conical dividing-screw *i i*. The fingers *k*, fixed to the finger-beam *l*, pass between the grain; and the knives cutting the grain fall on the Archimedean screws *n n*, *m m*, the platform *o o*, and third screw *p p*, which, revolving, pass the grain to this side of the machine. To the shaft carrying the wheel *e* a pulley *q* is fixed outside the framing; this carries a driving-belt *r r*, which passes over the pulley *s*, fixed to the extremity of the shaft of the screw *n n*; a pulley at the further extremity of *n n* carries a driving-belt *t*, which communicates motion to the other screws *m m*, *p p*. The chain *u u* is to raise or lower the platform *v v* as required by the lever-handle *w*.

1226. In fig. 461 we give a plan of the working parts of the driving apparatus, drawn to a scale of ½ inch to the foot. The main framing *n n n n*, fig. 461, the extreme length of which is 7 feet 3 inches, greatest breadth 3 feet 2 inches, and least breadth 18 inches. The driving-wheel *g g* is 2 feet 10 inches in diameter, keyed on a 3-inch shaft. This carries a spur-wheel *h*, 1 foot 9 inches diameter, which engages with a pinion *i*, 6 inches diameter. The shaft of this carries a bevel-wheel *k*, which engages with the pinion *a* keyed on the shaft *b*, carrying the crank *c*, which, through the medium of the connecting-rod *d*, gives a reciprocating motion to the cutter-blades. The bevel-wheel *k* is thrown in and out of gear with the pinion *a* by means of the lever *l l* operating on the clutch of the wheel *k*. The pole is inserted at *m*.

1227. In fig. 462 we give a plan of the finger-beam *a a*, with the shoe *b* and

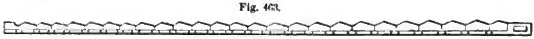
Fig. 462.



PLAN OF FINGER-BEAM—SCALE, ½ INCH TO THE FOOT.

fingers *c c*; and in fig. 463 a plan of the knife. The cutting parts of the knife are of steel, with serrated sickle edges, and are riveted to a malleable-iron bar by two rivets each.

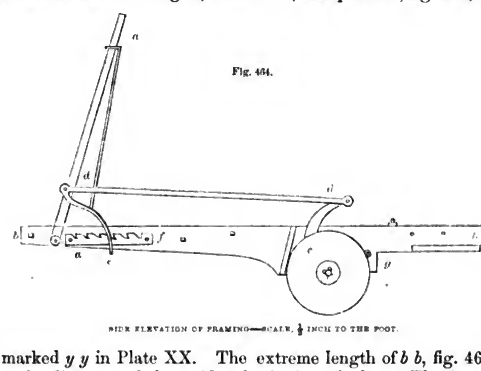
Fig. 463.



PLAN OF KNIFE—SCALE, ½ INCH TO THE FOOT.

1228. In fig. 464 we give a side elevation of the framing, at the side opposite to that which supports the driving-gear in fig. 461. This framing, fig. 464, supports the reel-braces *x x* in fig. 2, Plate XX.; the part *a a*, fig. 464, corresponds

Fig. 464.

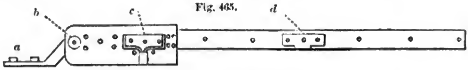


SIDE ELEVATION OF FRAMING—SCALE, ½ INCH TO THE FOOT.

to that marked *y y* in Plate XX. The extreme length of *b b*, fig. 464, is 6 feet 9 inches; the diameter of the guide-wheel *c* is 14 inches. The braces *a a*, *d d* are tightened up by the click or catch *e* entering the rack *f*. The end *d* of the finger-beam *a a*, fig. 462, is bolted at the part *g* of the side-frame, fig. 464.

1229. In fig. 465 we give a side elevation of the off-side of platform for supporting the delivery-screws. The part *a* is bolted at the point *e* of the finger-beam *a a*, fig. 462; *b* is the centre in which the extremity of the shaft of the

Fig. 465.

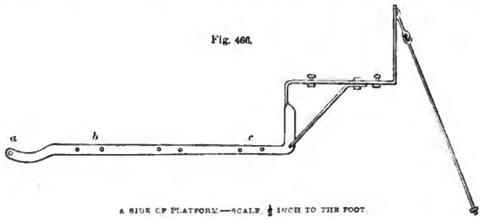


A SIDE OF PLATFORM—SCALE, ½ INCH TO THE FOOT.

screw *n n*, fig. 2, Plate XX., revolves; *c* that of the second screw *m m*; *d* that of the third screw *p p*; the platform *v v* being fixed at the point *e*, fig. 465.

1230. In fig. 466 we give a side elevation of the near platform-side marked, *z z* in fig. 2, Plate XX. The end *a* is bolted to the stud *f* in fig. 462. The pro-

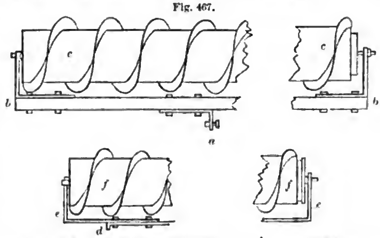
Fig. 466.



A SIDE OF PLATFORM—SCALE ½ INCH TO THE FOOT

jecting part *a*, fig. 467, of the frame *b b*, in which the screw *c c* (corresponding to *p p*, fig. 2, Plate XX.) revolves, is bolted to the side-frame, fig. 466, at the point *c*. The part *d*, fig. 467, of the frame *e e*, in which the screw *f f* (corresponding to *m m*, fig. 2, Plate XX.) revolves, is bolted to the frame, fig. 466, at the point *b*. The extreme length of first screw *n n*, fig. 2, Plate XX., is 4 feet 11 inches; diameter of central boss, 7 inches; diameter of blade or helix of screw 10 inches. The extreme length of second screw *m m* is 4 feet 6 inches; diameter of central boss, 8 inches; of helix or third, 11 inches. The length of third screw *p p* is 7 feet 3 inches; diameter of boss, 9 inches; of helix, 12 inches. The extreme length of central shaft of reel *h h h* is 7 feet 2½ inches; the diameter of reel 5 feet 10 inches; the length of the blades or beaters being 3 feet 6 inches; the breadth 7 inches. The diameter of pulley *g* is 13 inches. The letters *i i* point out the conical screw, the object of which is to bring the corn which lies away from the machine up to the platform. This is the most recent improvement introduced by Messrs Burgess and Key, and is admitted to be most effectual in its operation. In the older forms the place of this screw was filled by a tapered divider-board. This conical screw is worked by bevel-gearing 1, 1, which receives motion from the reel-shaft, through the medium of the pulleys 2 and 3, and belt 4.

Fig. 467.



PLAN OF DELIVERY-SCREWS AND FRAME—SCALE, ½ INCH TO THE FOOT

1231. The price of Burgess and Key's M'Cormick's reaping-machine is £42, 10s.

1232. Section Third.—*Thrashing-Machines.*

1233. *Thrashing-Machine.*—We have now arrived at one of the most important machines of the farm—one on which much has been said in regard to its history, and of which, although of comparatively recent introduction, the true merit of its invention is involved in some obscurity. Like most other inventions, it appears to have come to maturity not by one mental effort, but by a succession of steps, sometimes progressive, and at other times retrograde.

1234. As may naturally be supposed, the earliest attempts at machine-thrashing, of which there is any authentic notice, were imitations of the flail, a mode the most unlikely of all others to be attended with success. The county of Northumberland seems to have given birth to the first rational attempts, and that not longer ago than seventy years. The Northumberland experiments, in the hands of Mr Ilderton of Alnwick and Mr Osley of Flodden, though differing somewhat from each other,* and neither of them successful, contained the germs that led to the development of the perfect machine—not, however, without passing through other stages of probation.

1235. Amongst these transition steps is to be ranked the experiments and improvements upon the former machines by the late Sir Francis Kinloch, Bart., whose models, having been put into the hands of Mr Andrew Meikle, Houston Mill, East-Lothian, served as a groundwork for that ingenious millwright to fabricate the thrashing-machine in a comparatively perfect form;—perfect, indeed, in so far as the simple act of beating the grain from the husk was concerned. To Meikle, therefore, has been ascribed the merit of the thrashing-machine; and that he is entitled to this, as having produced the first really effective machine, there can be no question; but there can be as little, that those who pioneered the way, and brought the machine so near the mark, deserve their share of the merit. The previous machines appear to have contained the essential parts of the thrashing apparatus, the feeding-rollers and the beater or scutcher; and though it is usually alleged that Meikle gained the palm by having devised the *drum* with its beaters, yet we are now well aware that a close cylinder or drum is not by any means essential to thrashing, and that the beater, when set upon open arms, and revolving at the proper velocity, will perform the work perhaps better than with a close drum. The drum, however, has taken such hold on the minds of Scotch millwrights and farmers, that it has hitherto been little less than sacrilege to propose its dismissal: there is, however, every probability that the day is not distant that will see the drum beaten out of the barn by the long-rejected open beaters.

1236. It appears that the early thrashing-machines, even those that were held perfect, did nothing more than simply beat the grain out of the husk, the remaining processes of shaking and dressing being left for manipulation. These, however, appear to have followed in rapid succession; the revolving rake-shaker having been first added, and afterwards the dressing-fan.

1237. In the early stages of the machine, the whole of it generally stood upon the ground, barns in Scotland having not then attained a *loft* or first floor. The introduction of the shaker, but more especially the fan, induced the necessity, first of elevating the mill to a greater height on the ground-floor to admit of the application of these appendages, and ultimately rendering a first-floor a necessary part of the arrangements of a well-regulated thrashing-machine. By the disposal of the parts of the machinery in two floors, the whole business

* Brown *On Rural Affairs*, vol. i. p. 318.

is conducted in a more orderly manner, and a distinct separation of the unthrashed corn from the straw, the chaff, and the grain. The arrangement of the premises will be found illustrated in the Fourth Division of this book.

1238. *The Scotch Thrashing-Machine.*—Thrashing-machines may be divided into two great classes—English and Scotch—in the mode of operation of which there are marked differences. We shall first describe the Scotch thrashing-machine, as it may be said to be the precursor of the combined English machines now so much in use.

1239. The arrangement of the thrashing department of the steading with a complete machine consists of the following parts :—1. The upper or thrashing-barn, which contains the chief part of the machinery and the thrashing apparatus : here the unthrashed corn is received from the stackyard, and is delivered into the machine ; and here also the separation of the grain from the husk and the straw takes place in passing through the upper works of the machine. 2. The corn-barn, immediately below the former, and is part of the ground-floor ; here the grain, separated from the straw by means of the shaker and screen, is received, first into the fanners, where it is separated from the chaff, and delivered at two distinct spouts, the one giving out the partially-dressed grain, and called the clean spout ; the other, called the seconds spout, discharging a mixture of grain with some husks and a few unthrashed ears—which is again returned through the machine. 3. The straw-barn, into which the straw is received direct from the shakers of the machine. 4. The chaff-room, situate intermediate to the two former divisions, and is usually a portion of the corn-barn, partitioned off with boarding, the fanners forming a part of the partition.

1240. Besides the essential divisions of the process just pointed out, there are minor divisions which are chiefly carried on in the corn-barn. These may be taken in progressive order, and are—1. The elevator from the foul or seconds spout, raising the seconds to the feeding-board. 2. The elevator from the clean-spout, raising the grain from that spout of the first fanners to the hopper of the second fanners, and in some cases a third set of elevators, lifting the grain from the second to a third fanner. 3. The hummeller, chiefly used for rubbing off the base of the awn in barley, but occasionally applied also to the other grains for specific objects.

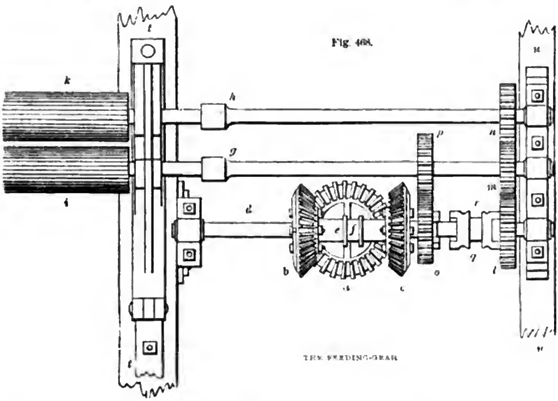
1241. *Details of the Framework.*—In describing the framework of the thrashing-machine, it is necessary to begin with that which supports the main shaft. This, it invariably falls out, has its bearing for one point in the wall that separates the barn from the locality of the power, whatever that may be. For this purpose, when the altitude of the position of the shaft has been determined, an opening of 2 feet square is formed in the wall, as at *f′* in fig. 2, Plate XXII., the sill of which should be of one solid stone, laid at the proper level, and upon which the pillow-block of the shaft is bedded. If intermediate wheels are employed, another and similar opening must be formed for the bearing of the shaft of the great spur-wheel. Such other shafts also as may require to be extended to the wall of separation, should have bearings in recesses formed in the wall at the respective positions, such as for the extension of the shafts of the drum and of the feeding-rollers, which, in general, may be arranged in one recess, as at *i* of the same figure. The sills and bearers in these minor recesses will be found more convenient if formed of good sound Memel timber, than of stone. In further describing the framework, the letters of reference apply to corresponding parts of fig. 1, Plate XXI., an elevation ; of fig. 1, Plate XXII., a longitudinal section ; and of fig. 2, Plate XXII., a plan of the machine. In these figures, *a* marks portions of the barn wall, *b b* the ground-floor line, and *c c* the foundation-beams, whose scantlings are 12 inches by 6 inches. The letter *d* marks the different parts of the framework of the case of the machine. Of these parts, the four posts which encase the drum *i i*, together with the two bearers on which it rests, are 5 inches square. The four posts, with their bearing-rails, that enclose the shakers *l n*, are 5 inches in breadth and 3 inches in thickness. These timbers are joined by mortise and tenon, so as to be all *flush* on the outward side. The whole of the posts are likewise tenoned into the sill *d*, which is 3 inches in breadth and 2½ inches in depth. The four drum-posts, being of greater breadth than the sill, are tenoned with a cheek at bottom of 2 inches in thickness, which passes down upon the inside of the beams, and is secured thereto by bolts, thus giving greater stability to the drum-framing. The top-rail *d* is also 3 inches in breadth by 2½ inches in depth, and is tenoned upon the head of the posts. The top-rails of the drum-casing are joined in like manner to their posts; but their dimensions are 5 inches by 3 inches. The position and form of the feeding-board is marked by the letter *e*; and as this appendage is not required of great strength, it is usually of a temporary construction, and sometimes even portable. The two sides of the framework thus described require to be tied by means of cross-rails, which are most conveniently fixed upon the top-rails of the framework by bolting.

1242. The openings in the two sides of the framing, formed as above described, are now to be filled in with panels of ⅝-inch boarding, neatly fitted and strengthened with cross-bars at each end of the pannel. Those panels that fill up the frame on the gearing side of the machine may be permanently fixed in their respective places; but all those on the other side must be made easily movable, for giving access to the different parts of the interior for the purpose of cleaning. In the panels that close up the drum-case, it has been recommended to leave an opening of 6 inches diameter round the shaft, for the purpose of admitting a current of air, which, it is supposed, might prevent the winding of straw round the shaft and ends of the drum. When the construction is good in other respects, it does not appear that this precaution is necessary; but the simplicity of the proposed remedy recommends it to attention.

1243. *Gearing of the Thrashing-Machine.*—Intermediate gearing is, in some cases, required between the power and the great spur-wheel. These are again represented by the dotted circles *m* and *n* in fig. 2, Plate XXI., where *n* is the wheel attached to the engine-shaft, and *m* that upon the shaft of the great spur-wheel. These, together with the latter, may be considered as common to all thrashing-machines, except those driven by a belt; but there are two principal modes of constructing all the inferior gearing, the one by means of toothed wheels, the other by pitch-chains and wheels adapted to the chains. The fig. 1, Plate XXI., and figs. 1 and 2 in Plate XXII., being those in which the toothed-wheel system is adopted, we shall first advert to them.

1244. *The Toothed-Wheel System.*—The great spur-wheel is marked *f*, fig. 2, Plate XXII.; upon its shaft is also placed one of the mitre-wheels *g′*; its fellow is mounted on the oblique shaft *g*, which gives motion to the feeding-rollers through the intervention of the triad of mitre-wheels *h*. Of these two sets of wheels, the lower *g′* may be from 12 to 15 inches in diameter, with a pitch of 1¼ inch and a breadth of 2½ inches. The upper, or triad *h*, are about 7 or 8 inches diameter, with a pitch of 1 inch and a breadth of 1½ inch. These, acting upon a train of small gearing, produce the requisite changes of the feeding-rollers, it being kept in view that the oblique shaft *g* should make either from 45 to 50, or from 65 to 70 rotations per minute; and to effect this, if the great spur-wheel make any number intermediate to these, the velocity of the shaft g is brought up or down, as opinion and circumstances may advise, by using bevelled wheels of different diameters, suited to bring out the required velocity, instead of the mitre-wheels g'. In the case now before us, the spur-wheel f is understood to make 50 revolutions per minute, and is therefore adapted through the mitre-wheels g' for the lowest rate of the feeding-rollers.

1245. *Feeding-Gear.*—Fig. 468 is an elevation of the feeding-gear, in which



THE FEEDING-GEAR.

$t\ t$ is a part of the drum-framing, and $u\ u$ a bolster attached to the wall; and though subject to great variety, the arrangement represents a simple and completely efficient train of gearing. a is the driving mitre-wheel of the triad h in fig. 2, Plate XXII.; b and c are the two other wheels, these last being mounted on the shaft d. The wheels b and c are connected together by a tube e; and this combination is fitted to *slide* upon the shaft d, but is prevented from turning round upon it by means of a feather or rib inserted in the shaft, the tube being also grooved to receive the rib. The tube is further provided with an annular groove f, formed by two raised collars. The groove f admits of a forked lever, by which the combined wheels b and c can be moved from right to left, or from left to right. The tube e is of such a length as admits of both wheels b c being placed out of gear with a; and, of course, when slid to the right, b comes into action with a, which turns the shaft d in one direction; but if slid to the left, b is disengaged, and c is brought into contact with the wheel a, and the shaft d is then turned in the opposite direction, while a continues to move always in one direction. The object of these counter-motions is to enable the person who feeds in the sheaves of corn to reverse the motion of the feeding-rollers when, on any occasion, it is found necessary to make them disgorge the straw.

1246. The object of the remaining wheels of the train is to change the velocity of the feeding-rollers, and is accomplished by the following combination: The shaft d, having a velocity already given to it of 50 turns per minute, which is suited to the lower velocity of the rollers, it is only necessary to communicate that to the rollers as one of their two rates.

The shafts *g* and *h* are respectively the prolongation of the lower and upper feeding-rollers *i* and *k*, connected thereto by the universal joints *g* and *h*, and each of the shafts *g h* are furnished with the equal spur-wheels *m n*, each of 12 teeth, working continuously into each other; while *l*, of 16 teeth, is fitted to run loose upon its own shaft. The wheels *o* and *p* have each 14 teeth, *o* being also fitted to run loose on the shaft *d*, and *p* fixed dead upon the shaft *g*; the two pairs, therefore, *l m* and *o p*, are always in gear. The slide-clutch *q*, with a slide-rib, being now placed on the shaft *d*, between the wheels *l* and *o*, which, as well as the slide, are furnished with clutch-forks, and so disposed that the slide can be clutched to either of the wheels *l* or *o*, or it may stand free of both,—and being always carried round with the shaft by means of the rib, and movable at all times, right or left, by a lever acting in its annular groove *q r*,—the man whose duty it is to feed can at pleasure stop all motion of the rollers, by placing the lever of the slide in a middle notch, give the rollers the highest velocity by clutching the slide into the wheel *l*, or their lowest velocity by disengaging it from *l* and clutching the wheel *o*; the former being effected through the wheels *l m n*, the latter through *o p m n*. In either of these cases, the disengaged wheel continues to be driven free of the shaft, by their respective companions *m* and *p*. The action of the slide-levers, by which the mitre-wheels *b* and *c*, and the spur-wheels *l* and *o*, are moved, will be more distinctly understood by turning to *h*, in fig. 2, Plate XXII., where the apparatus just described is seen in plan.

1247. When it happens that the great spur-wheel has a velocity that suits the highest velocity of the feeding-rollers, and that the wheels *g′*, fig. 2, Plate XXII., are still mitres, the train of small spur-wheels is somewhat changed. The wheels *l* and *m*, fig. 468, change places, and are, besides, moved their own breadth towards *o* and *p*; *o* and *p* are likewise shifted to admit the slide, but do not change places. A sixth wheel of the same number, as *n*, is then fixed on the shaft *g*, acting constantly in *n*. When the slide is now clutched into *o*, the highest velocity is produced; and when into *l*, the lowest is given out.

1248. When, again, it happens that the great spur-wheel has a velocity not agreeing with either the highest or the lowest velocity of the feeding-rollers, and the mitre-wheels *g′*, fig. 2, Plate XXII., are still retained, the arrangement is again somewhat different. In this case the wheels *m* and *n*, fig. 468, remain upon their respective shafts, but are shifted their own breadth to one side. Suppose the velocity of the spur-wheel, and that of the oblique shaft and its wheel *a*, to be 60 revolutions per minute, the wheels *l* and *m* must take the inverse proportion of 60 to 65, or say 70, for the high velocity; and the wheels *o* and *p*, instead of being equal, take the inverse proportion of 70 to 60 for the lower velocity. It were endless to multiply examples; it is sufficient to show the general mode of procedure, as every change of circumstance requires a new calculation.

1249. The arrangement of the feeding-gear has undergone many changes. Some of the older methods were sufficiently inconvenient and unscientific; but improvement has gradually made progress, and, though the varieties are numerous, they may be considered generally as efficient. The arrangement here detailed seems to possess every appliance that the case requires; it can be instantaneously adjusted while the machine is in motion, and yet it is free of complication and of liability to derangement. The couplings of the shafts we have called universal joints, par. 1246, but they hardly claim that appellation, nor, in the case of the lower shaft *g*, fig. 468, is that principle required; in the upper shaft *h*, the principle of universality of motion is, however, necessary to accommodate the rising and falling of the upper roller with the quantity of feed, while the end *n* of the shaft lies in a permanent bearing. This coupling, as usually formed, is simply a box or socket formed on the end *h* of the shaft, and in its cross section the box is usually oblong, being 1½ inch by 1 inch, or a little more, while the corresponding end of the roller-shaft is formed to fit so loosely into this socket as will allow the shaft *n h* to rise to an angle of 10° with the horizontal line, and this it must be capable of doing in any part of its revolution. This mode of coupling being so simple, is also applied to the shaft *g*, though, having no change of direction to encounter, the yielding joint is not essentially necessary. The shafting of this gearing is usually 1¼ inch in diameter.

1250. *Gearing of the Drum.*—The drum, as the principal member of the machine, requires the most direct means of communicating the power to it; hence the pinion of the drum is usually driven directly by the spur-wheel; but it is also necessary, with the high velocity at this point, to produce a smooth action, and the difficulty and expense of procuring this, when rough cast-iron is employed, is such, as to have induced the practice of employing cogged wheels, now in most cases adopted. By the term cogged wheel is now understood any wheel, the eye, arms, and rim of which are of cast-iron, but having the teeth formed of hardwood, generally beech, set firmly in mortises previously cast in the rim; hence such wheels, in the language of the mechanic, are frequently called *mortise* wheels. (See fig. 171.) The great spur-wheel *f*, then, fig. 1, Plate XXI., and 2, Plate XXII., is a cogged wheel of 5½ feet diameter, having 120 teeth, the pitch of the teeth being 1¾ inch, and the breadth 4 inches. This drives the pinion *i*, which is placed upon a prolongation of the drum-shaft, the prolonged part being coupled to the true shaft immediately outside the framework, as seen in fig. 2, Plate XXII., between *d* and *q*, though some makers prefer that the whole be in one piece. The pinion *i* of the drum is here 12½ inches diameter, with 22 teeth; and, as ought always to be done in the case of a pinion being driven by a cogged wheel, the pinion is turned true upon its own shaft, the cast teeth correctly graduated afresh, the correct curve drawn upon them, and the whole dressed off to equality by the chisel and file. For this purpose, pinions that are to be *dressed true* must be cast with their teeth of such extra thickness as will admit of this dressing, and still possess the due thickness and strength required for true action.

1251. *Gearing of the Shakers.*—The shakers being required to move at a velocity considerably lower than the drum, and even lower in general than the great spur-wheel, a reduction of velocity becomes necessary. In the arrangement under consideration, this is effected by extending the main shaft *f′*, fig. 2, Plate XXII., by means of a coupling-piece extending to, and resting on, the beam *c*. This extended part of the shaft carries the small wheel seen at *k* in the same figure, but is hid in fig. 1, Plate XXI., by the eye of the great spur-wheel. This small wheel is 10 inches diameter, and acts upon the intermediate wheel *k*, which is not furnished with a shaft, but turns upon a strong fixed stud. The wheel *k* acts upon *l*, which is fixed upon the shaft of the first shaker *l*, and of fig. 1, Plate XXI. The continued train of spur-wheels *l m*, *m n*, together with *k*, are all of one size, 2 feet diameter, 1⅛ inch pitch, and 2 inches broad. Of these *m m* are also intermediate, or applied to convey motion from *l* to *n*; *n* being fixed upon the shaft of the second shaker, while *m m* turn upon studs like *k*. These studs are inserted into a swing-bar that can be bolted to the horizontal rails of the framing, in such position as will bring the intermediate wheels into proper pitch with the principals *l* and *n*.

1252. *Gearing of the Fanners.*—The motion for the fanners is taken with great convenience from the drum-shaft, on the extension of which is placed a grooved pulley of 9 inches diameter, at *q*, fig. 2, Plate XXII.; a corresponding pulley *s*, fig. 1, Plate XXI., is placed upon an extension of the fan-shaft of the fanners, the extended part being coupled to the principal shaft of the fan immediately adjoining to the pulley, and the extreme end supported in a bearing on the post *t*. The driving-pulley *q* being 9 inches diameter, and making about 360 revolutions per minute, the pulley *s*, in order to bring the fan to a proper velocity of 220 revolutions per minute, requires to be made about 14½ inches diameter. Since these two pulleys stand at right angles to each other, and the rope-band (usually employed) cannot, for that reason, apply directly to them, it requires to be carried in the direction *q r q s*, fig. 1, Plate XXI., *r* being a slide-frame in which two leading pulleys, mounted in a case, are fitted to slide in the vertical direction, thus serving at the same time to lead the band in the proper direction to the pulleys *q* and *s*, and to tighten or slacken the band. The pulley-case is moved in the slide, either by a long screw or by a tail-rope, which, when the case is adjusted, is fastened to a cleat.

1253. The second fanners *a′*, fig. 1, Plate XXI., are most conveniently driven by a band of rope or leather *c′ c′*, from a pulley set upon the extreme end of the drum-shaft; but this, in all the figures, is hid from view by the adjacent parts. The band passes down through the floor, and directly under the corresponding pulley on the fan-shaft. The pulleys for this purpose are of the same diameter as those described for the first fanners.

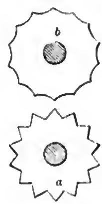
1254. *Gearing of the Elevators.*—The methods of giving motion to the elevators are numerous, depending frequently on the arrangement of the machinery, and sometimes on that of the barn. The one here adopted is, by placing a chain-wheel on the great spur-wheel shaft immediately behind the mitre-wheels *g′*, fig. 2, Plate XXII. A corresponding wheel *v* is placed on a shaft appended to the lower side of the foundation beams by plummer-blocks, and reaching across both beams. Over these wheels the pitch-chain *u u*, fig. 1, Plate XXI., is applied, which gives motion to *v*. On the shaft of the wheel *v*, and at a point directly in front of the clean spout of the fanners *p*, are placed two plain wheels or pulleys *x*, of about 14 inches diameter; these carry the belts of the elevator *w w*, which, by descending to the lower pulleys, becomes the driver of the elevator *y y*, the lower pulleys of both being on one shaft. Corresponding to this last pair of pulleys, there is also placed in the upper barn, at a sufficient height above the feeding-board, another pair of pulleys, one of which, *y*, is seen at the upper extremity of the elevator *y y*, fig. 1, Plate XXI., and placed on a shaft appended by plummer-blocks to the collar-joists of the roof. Thus arranged, the chain *u u* gives motion to the elevator *w*, which, in its turn, through the medium of the lower pulleys *x*, and their shaft, gives motion to the elevator *y*.

1255. In cases where elevators for the foul spout only are employed, the chain *u u*, fig. 1, Plate XXI., is carried to a chain-wheel placed on the shaft of the pulleys of the upper extremity of the elevator *y*, or, if circumstances render it more convenient, to the lower extremity *x*; and in either case, it is obvious that the elevator *w*, instead of being the driver, may be made that which is driven.

1256. Having considered the construction of the framework, and the application of the gearing of the thrashing-machine, we proceed to notice the construction and action of the active parts of the machine, and their relation to each other.

1257. *Of the Feeding-Rollers.*—The feeding-rollers have had their varieties of change, and these varieties have arisen from attempts to overcome an accident to which feeding-rollers are liable when thrashing corn in a damp state—the winding of straw around them. To obviate this, rollers have been made, both plain, and both fluted in various forms; they have been made of hardwood, and wrapt spirally round with hoop-iron; have been turned truly round in cast-iron, and fitted up with scrapers constantly acting upon them, to prevent adhesion of the straw; and with one fluted, and one plain, without being turned true. The forms now most generally adopted in Scotland are represented in fig. 469, where *a* is a transverse section of the lower roller, fluted in an angular form; while the upper roller has its transverse section, *b*, forming a polygon, whose sides are slightly concave. In both, the breadth of the flutings and of the faces are from $\frac{3}{4}$ to $\frac{7}{8}$ inch. In the Scotch thrashing-machine the rollers are invariably made of cast-iron, with journals or gudgeons of malleable iron, either cast into the roller, or afterwards fixed in with wedges. Their diameter is usually 4 inches; and for their length, it is always desirable that it be 1 or 2 inches greater than that of the drum. The weight of a roller, therefore, of $3\frac{1}{2}$ feet in length, will be about 140 lb. The velocity of revolution of the feeding-rollers is a point of great importance in this species of thrashing-machine, and is affected by various causes, such as the length of straw in the wheat compared with that of the barley and oat crops. The state of the crop also requires to be considered as to its dryness and dampness, with other causes arising from soil, climate, &c. Independent of these considerations, if the rate of feeding be too slow for the velocity of the drum, the work will be slowly performed, and the straw will be much broken. If, on the other hand, it be too fast for the drum, the corn will pass through imperfectly thrashed; both of which results it is desirable to avoid. The results of the experience for many years of numerous millwrights, have determined a mean range of velocities which appear best suited to obviate the greatest number of difficulties. These velocities, when stated in terms of that of the drum, are, that the rollers of 4 inches diameter make one revolution to five of the drum as the maximum velocity, and one to six and one-third as the minimum. When compared by the spaces over which the straw is passed in a given time between the rollers, the maximum rate is 73 feet, and the minimum 57 feet per minute. Or, taking the number of strokes of the beaters in a given length of straw, we have, in round numbers, 24 strokes on 1 foot of length of straw as the maximum, and, for the minimum, 19. Some makers, it may be remarked, make the maximum higher, and the minimum lower, than the above rates; but unless a third or mean velocity could be obtained, which no doubt could be done, there seems to be no advantage gained, from pushing the extremes—the maximum and minimum rates—beyond reasonable limits.

Fig. 469.



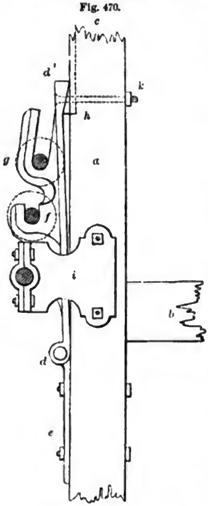
TRANSVERSE SECTIONS OF THE FEEDING-ROLLERS

1258. The rollers are usually placed in front of the posts of the drum-framing, and the lower one at a height of from 3 to 5 inches above the level of the drum's centre: the lower we hold to be the better of the two. The upper roller, of course, lies upon the lower when not in action, with straw between them. They are supported in brackets of various forms; and as it is necessary that means be afforded to vary the distance of the rollers from the beaters, numerous methods have been taken to accomplish this, by varying the form and means of applying these brackets or bolsters.

1259. We have, in the course of our practice, applied a very perfect and easily-managed form of bracket, but which is, perhaps, too expensive for the remuneration afforded from the making of thrashing-machines. The principle of the method is: the two brackets are fitted to move horizontally in a metal slide, and their movement is effected by a screw passing into each. Each of the screws is mounted with a small mitre-wheel, serving as the head by which it is turned. A slender shaft extends from the one bracket to the other, and carries two more mitre-wheels, which act upon the two former. A handle is fitted to the slender shaft, and, by turning this either way, the screws are acted upon through the mitre-wheels, and ultimately on the brackets, to move them backward or forward simultaneously, and with the greatest precision.

1260. A simpler and very efficient method has also been adopted, which is represented in fig. 470, where *a* is a front post of the drum-framing, *b* a part of the bearer of the drum, and *c* the place occupied by the top-rail; *d d'* is the bracket, *e* is a tail, hinge-jointed at *d*, and is bolted dead upon the post; *f* is the bearing of the lower roller, and *g* that of the upper, which is formed as a curved slit concentric to the circle of the drum. At the top *d'* of the bracket, and on the back part, a wedge-form piece is cast upon it, forming an inclined plane. The reverse wedge *h* is of malleable iron, forked or slit from the head towards the tail, to pass over the bolt *k*, and terminates in a screw and nut; the tail is sunk into the post, and passes upward through the top-rail *c*, where it is held in the position required by the screw-nut. It is obvious that, by drawing the wedge *h* upward, it will press the head of the bracket outward; and the nut of the bolt *k* being then screwed tight, the bracket will be held fast and secure. A separate bracket *i* is bolted upon the post *a*, serving as a bearing for the shaft *d* of fig. 468.

Fig. 470.



THE BRACKETS OF THE FEEDING-ROLLERS.

1261. *Of the Drum.*—The construction and properties of the drum, as it is the prime member of the machine, require the most careful consideration. In the Scotch practice, it is invariably made a close cylinder. The shaft, always made of malleable iron, is usually 1¾ inch square, sometimes 2 inches, and rarely 1½ inch. Upon this is mounted generally two sets of crosses or arms of hardwood. The quality of lightness, especially towards the central parts, with a due degree of strength, being of great importance, these arms should be of the best and toughest materials. Their dimensions at the centre need not exceed 4 inches by 2½ inches, tapering to 2½ inches square at the ends. They are half-lapped in pairs at the centre, and strengthened by a plate of malleable iron on each side, with a bolt on each arm, passing through the plates and arms. By means of these plates, also, they are firmly wedged upon the shaft, one set of arms being placed at each end. Fig. 471 is a transverse section of the drum thus constructed, showing the shaft *a*, the plates *b*, and the arms *d*. To these are added, upon each set of arms, a ring of hardwood *e*, worked in segments, and bolted to the arms. This ring, 2½ by 1½ inches, and 28 inches of external diameter, besides binding the extremity of the arms, serves as a bed for the covering, which is now always made of sheet-iron of the strength of 1½ lb. per superficial foot. The portion of the arms that projects beyond the ring serves as the bearing to which the beaters *f* are bolted; these are $3\frac{1}{2}$ inches in depth, and 2 inches in thickness. The striking face of the beaters is formed to lie in the radii of the circle, and is faced with an iron plate from end to end, the breadth of which may be from 2 inches to $1\frac{1}{2}$ inch, usually steeled on the striking edge with a thickness of $\frac{3}{8}$ inch, and securely fixed with bolts or screws. The ends of the drum are covered with $\frac{3}{4}$-inch boarding, and dressed off truly by turning.

1262. Such is the construction of the drum most frequently adopted; but other methods are also followed. In some cases, arms of cast-iron instead of wood

Fig. 471.

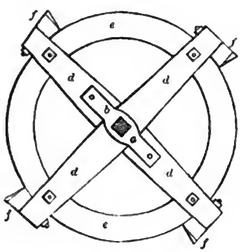
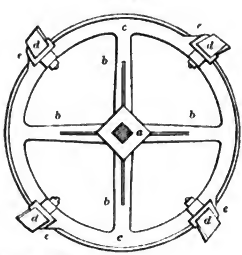


Fig. 472.



TRANSVERSE SECTIONS OF THE SCOTCH DRUM.

are employed; and these, if judiciously proportioned, are, in some respects, superior to wood—all the other parts outward remaining as described in par. 1261.

1263. A third method has also been adopted, wherein the arms and ring are in one piece of cast-iron, comparatively light. Fig. 472 represents this mode of construction in transverse section, where *a* is the shaft, *b* the arms, 2 inches by $\frac{1}{2}$ inch, and *c* the ring, having the same dimensions; its diameter over all being 2 feet 6 inches. In this the beaters *d* are only 3 inches in depth; they are bedded upon a flange projecting on each side of the ring, and bolted in that direction, but supported, besides, by the lip *e*, which rises and supports them behind in the direction of the stroke.

1264. The position of the drum in relation to the feeding-rollers has been already stated (1241); its distance from them ranges from $\frac{1}{2}$ to $\frac{3}{4}$ inch, the mean of these being the distance most generally acted upon. The height of the drum's centre above the floor of the barn varies, with local circumstances, from 1 foot to 2 feet, there being no special rule to confine it to any precise height between these limits.

1265. The diameter and length of the drum has undergone many changes. In the early period of its history, it appears to have been of moderate dimensions, but with the extension of the use of the machine came an impression that its parts should be also extended; and, accordingly, about thirty years ago we find the length of the drum extended to 5 and even to 6 feet, and its diameter to $3\frac{1}{2}$ feet. These, no doubt, are extreme cases. But the general opinion then was, that a large drum was the only means by which a large quantity of work could be performed. During the last twenty years, opinions have taken the contrary direction, and the drum has returned to more reasonable dimensions. This last change has, no doubt, been in part brought about by the introduction of steam as a thrashing power, for by it a machine that with 6 horses could, with an effort, thrash 30 bushels of wheat per hour, will now, with a 6-horse-power engine, thrash with ease 45 bushels in the same time, and that with a drum not exceeding 3½ feet in length and 3 feet diameter: there is now, therefore, a general disposition to approach these dimensions as a standard. With such power, it has been found that one man can feed for the thrashing of 45 bushels per hour, or even as high as 60 on an emergency; but even with the latter quantity, and though the drum were 5 feet long, the spread of the corn does not extend beyond 3½ feet of its length, or more properly to only 3 feet of it; hence all that is over the greatest of these is superfluous length, and ought to be removed. Since a machine with a drum of 3½ feet is capable of thrashing 450 bushels in 10 hours, the whole produce of a farm of 500 acres could be thrashed in from 30 to 40 days, which seems abundantly expeditious; and, therefore, the maximum length of drum may be fairly taken at 3½ feet for a 6-horse-power engine; and, by the same calculation, 3 feet for a 4-horse power, and 2½ feet for a 2-horse machine, the diameter of the drum in all cases remaining the same—3 feet. Under the system that admitted of large drums, the number of revolutions was necessarily low, and during these periods it was generally limited to 300 per minute, which, with the diameter of drum then used, gave an annular velocity, at the extremity of the beaters, of about 3300 feet per minute. With the changes related above, the number of revolutions has been increased, while the diameter has decreased. The medium rate now employed is 350 revolutions per minute, but frequently 400: with 350 revolutions, the velocity of the beaters continues nearly the same as when the large drum was employed; but with a rate of 400, the velocity amounts to 3300 feet per minute. There is good reason for concluding that a mean velocity of 3500 feet per minute will yield the maximum effect under the system of thrashing herein described.

1266. In the Scotch thrashing-machine the action of the beaters is upward; and this, with very few exceptions, is invariable. From the construction of the thrashing parts of the machine, the corn is kept under the action of the beaters for a very short space; for, however well the feeding-rollers may hold on the straw, the ear passes beyond the reach of the beaters, when it has passed over about one-fourth part of the circumference of the drum-case. This we hold to be a defect in the machine, and that to this defect may be ascribed almost all those complaints of imperfect thrashing, not unusually ascribed to defects in the shaking department. In another class of thrashing-machines, this defect is obviated by retaining the straw under the action of the beaters during its passage over at least two-thirds the circumference of the drum-case; and there appears every reason to conclude that the thrashing process of the Scotch machine would be much improved by adopting a similar arrangement, and which could be easily effected.

1267. *Of the Drum-Cover.*—The thrashing process is accomplished by subjecting the corn and straw to the action of the beaters, while it is held by the feeding-rollers. But in order to give full effect to the blows of the beaters, the straw is resisted and held to the action by means of the apron or cover of the drum. The cover is a strong concave board *i″*, fig. 1, Plate XXII., equal in length to the drum, and in breadth measures about 27 inches. The boarding is 1 inch in thickness, and is fastened by nailing it upon three segmental bars, placed outside, of hardwood or of cast-iron, the concave surface being also lined with sheet-iron. The radius of curvature of the interior surface is 3 inches greater than that of the drum itself; and it is suspended at its upper edge by a swing link, capable of being shortened or lengthened at pleasure by a screw. The average distance of the upper edge of the concavity from the beaters is about

3 inches, while the lower edge coincides with a circle that would touch the feeding-rollers, or about $\frac{5}{8}$ inch distant from the beaters. Different methods are followed in forming the junction of the feeding-rollers with the apron.

1268. In some cases, the front edge of the apron is cut off nearly vertical, so as to allow the upper feeding-roller to pass the apron when raised up by the feed. In this case, the lower edge of the apron forms an acute angle, and is supported in a swing link similar to that of the upper edge.

1269. Another method is to rest the lower edge of the apron on the journals of the upper roller by means of a gland at each end, bolted to the lower edge of the apron, and having a bearing on the journals. In this case, the lower edge of the apron is worked off to the curvature of the roller to a small extent, and keeps always close upon but not touching it.

1270. By these means, the lower edge of the apron rises and falls with the roller; and when so rising and falling, it swings upon the upper link, and the roller has consequently the weight of the apron always upon it. When the straw has passed the apron, it is prevented from flying off by a plain board *d′* placed in a tangent to the curve of the apron, as in the figure, which leads it directly from the apron to the shakers.

1271. The casing of the drum is completed by having an arc *k*, fig. 1, Plate XXII., formed underneath, extending from the rollers at *h′* to the breast of the casing at the top of the inclined plane *i″*, its position and curvature being such as just to allow the beaters to revolve freely. This part of the casing is formed of 1-inch boarding laid upon three segmental ribs of hardwood *k*.

1272. In the operation of the drum, it is occasionally, from the state of the straw, subject to an inconvenience arising from an accumulation of straw between the ends of the drum and the casing-boards. This seems to occur only where an unnecessary wide space is left between the ends of the drum and the boarding. With due care, this space may be reduced to $\frac{1}{8}$ inch, but should never exceed $\frac{1}{4}$ inch; and by attention to this on the part of the maker, all inconvenience from this cause may be avoided. (See par. 1242.)

1273. *Of the Shakers.*—Next in importance to the drum stands the shaking apparatus, for separating the loose grain from the straw. That mode which is of the longest standing, and by far the most generally approved of, is the *rake* shakers *l* and *n*, figs. 1 and 2, Plate XXII. They are variously formed, having sometimes a close cylindrical body like the drum, with rake-heads projecting from it, as in *n*. It is also formed with a square and with a pentagonal body, the rake projecting as before; and lastly, a square form, with concave sides, which, uniting at the angles, shoot out into the rake-heads, as in *l*, which is a form that has been well established for a first shaker, the concave spaces affording good range for the reception of the grain and straw from the drum. In the construction of this shaker, two very light frames of cast-iron, of the form represented in the figure, consisting of the four arms, about $1\frac{1}{2}$ by $\frac{3}{4}$ inch, and the four concave sides having the same scantling, after their junction, proceed to the distance of 27 inches from the centre, when they are turned off into the palm, which stands at an angle of 45° with the direction of the arm. The entire length of the shaker should be 4 inches, at the least, longer than the drum; and the two frames just described are set upon the shaker-shaft, at about 5 inches within the intended length. The rake-heads are $2\frac{1}{4}$ inches square, and of the full length of the shaker; they are bolted to the palms of the frame, and are bored for the insertion of the spikes or teeth, which are set on the heads at spaces of about 4 inches apart, their length being about 8 inches beyond the head. In the several heads, the same distance apart is observed for the teeth;

but they are so arranged in each, that those in any one rake follow a different track from the teeth of any of the other three heads. The radius of the shaker, measuring to the extreme points of the teeth, is 3 feet; and the distance of these from the beaters is usually about 9 inches. In all cases, the grain and straw pass under this shaker, and the position given to the teeth has the effect of pressing the straw down upon the grating while in progress over it, producing thereby a process of rubbing, to aid the discharge of the grain. But so soon as the straw is relieved from the friction of the rake, the same position of the teeth discharges it with certainty upon the second shaker.

1274. The second shaker *n*, figs. 1 and 2, Plate XXII., has also undergone various changes; but, in general, it is either a close or a skeleton cylinder, with rakes attached. Some makers prefer sending the straw over the top of the second shaker, and there is good reason for recommending this practice. When this practice is adopted, the shaker is necessarily of the skeleton make, to allow the grain to fall through it; and the present example is upon this principle. It consists of two sets of arms, each extending to a radius of 21 inches, when each arm terminates in a palm, standing at an angle of 22° with the direction of the arm. A ring of hardwood, $2\frac{1}{2}$ inches by $1\frac{1}{2}$ inch, and 3 feet 4 inches diameter, is bolted upon each set of arms, and they are thus set upon the shaft 5 inches within the extreme length of the shaker, as before. A series of triangular laths are then nailed upon the rings, their length forming the body of the shaker, and set at 4 inches apart. Four rakes, formed as described for the first shaker, are bolted upon the palms, which complete the structure; and the radius in this case, taken to the point of the teeth, is 2 feet 6 inches. There is sometimes a necessity for the adoption of this kind of shaker, namely, when the barn is so low that the great hopper cannot be extended under the whole length of the grating of the second shaker without giving the hopper such a low angle, that grain, particularly barley, would lodge upon it. To obviate this, a part of what ought to be grating is boarded over, as at *n'*, fig. 1, Plate XXII.; and to prevent grain from accumulating upon this, brushes are applied over one-half of two opposite rakes, the teeth in these parts being left out, and the brushes attached by means of adjusting screw-bolts, by which the brushes are adjusted to sweep the grain into the grating.

1275. It will be observed that, when the second shaker takes the straw *over*, and if driven by wheel-gearing, the two intermediate wheels *m m*, fig. 1, Plate XXI., are required; but if the straw is taken *under*, then the shaker revolves in the opposite direction; and to effect this, one intermediate wheel only is required; in which case, also, the wheels, instead of being 2 feet diameter, will require to be 3 feet 2 inches, or thereby. In the case of working under, also, the rake-teeth must be placed at the angle 45°, as in the first shaker.

1276. The position of the shakers vertically, in relation to the drum, may, without detrimental effect, be varied according to local circumstances; but with a 6-feet first shaker, its centre should, on an average, be 9 inches above the level of the drum's centre. This will give the plane *l''*, fig. 1, Plate XXII., leading from the drum, an inclination of about 40°, which will be sufficient to prevent any accumulation of grain or straw in that part of their course. The centre of the second shaker, of 5 feet diameter, may be placed anywhere between that of being on a level with the first shaker to 6 inches below its level; the height of the barn being, in this respect, the principal object of consideration, in order that the spread of the great hopper *o* may be as great as possible, which, it will be observed, is shortened by lowering the second shaker. The velocity of the shakers is the last point of importance; and on this it may be observed, that the smaller the quantity of straw in the grasp of the shaker at any one time, so much the better will the work be performed. This will be effected by giving the shakers the highest velocity at which they will deliver the straw, without risk of carrying it round on the teeth of the rakes, and these points will be obtained by giving the shakers a velocity of from 25 to 30 revolutions per minute.

1277. *The Screen or Grating.*—The screen, over which the straw is carried by the action of the shakers for the final separation of the grain from the straw, extends from the breast of the drum-case, following the curve of rotation of the shakers, onward to the extremity *n'*, fig. 1, Plate XXII. The plane *l''* is close-boarded, and covered with sheet-iron, in the position as described in par. 1276. At the bottom of this inclined plane, the screen proper begins.

1278. The screen is formed in various ways, some makers using a cast-iron grate, with square meshes, of $1\frac{1}{2}$ inch on the side, the iron being $\frac{5}{16}$ inch in thickness and $\frac{1}{2}$ inch in depth.

1279. Others apply splits of deal, $\frac{5}{8}$ inch thick and $1\frac{1}{2}$ inch in depth, placed at intervals of $1\frac{1}{4}$ inch in width, the splits being crossed by other splits of the same breadth, but only $\frac{3}{8}$ inch in depth, placed at intervals of $2\frac{1}{2}$ inches.

1280. A third method may also be recommended as strong and durable, composed entirely of straight rods of malleable iron, $\frac{1}{2}$ inch diameter, and laid at intervals of $\frac{5}{8}$ inch.

1281. The iron grating and the malleable-iron rods, though the most expensive, are very efficient, and are the most durable. In all the three methods, the gratings are supported on segments of hardwood *l' m''* and *m' n'*, worked off to their respective circles, and nailed to the foundation beams and framing; and when the machines are of the widest, a central segment is also applied to support the middle of the splits or rods. The portion *n'* lying beyond the great hopper is close-boarded, and a continuation of this, marked *o'*, is placed in a sloping direction, to carry the straw over the wall, and deliver it upon a sloping rack placed in the straw-barn.

1282. *The Great Hopper.*—The dimensions of the hopper *o*, fig. 1, Plates XXI. and XXII., are regulated by the height of the barn and the breadth of the machine; the breadth of the hopper at the upper part being equal to the length of the shakers, and its length is adapted to the extent of the grating. The bottom of the hopper is adapted to the width of the fanners in one direction, and is usually from 20 to 22 inches in the other direction. The inclination of the ends should never be lower than an angle of 55°; the sides will always fall to have a sufficiently high angle. The entire hopper is formed of $\frac{3}{4}$-inch boarding, and its object is to collect the grain from the grating, and to deliver it into the fanners.

1283. *The Fanners.*—The first or machine fanners *p*, fig. 1, Plates XXI. and XXII., are placed in a central position under the gratings *l'* and *m'*, so that the two ends may have equal slopes. The height of the fanner-case is about 5 feet, and the extreme length 8 feet. The width is a point on which great difference in practice exists, some makers being satisfied with a width of 20 inches, while others give 36 inches, the power of the machine being the same. These extremes we consider to be both in error, and that a width of 26 to 30 inches is sufficient for every purpose. The details of the first fanners being so much akin to those of the second or barn fanners, we shall leave them to be treated of more at large under Barn Fanners.

1284. *The Elevators.*—The elevators are simply a chain of buckets, sometimes attached to actual chains, but more frequently to leathern belts. The buckets *y y*, from the foul-spout of the fanners *p*, fig. 1, Plates XXI. and XXII., are 14 inches in width, scoop-shaped, with a depth of 4 inches and a length of 10 inches. The ends *y y* are formed of hardwood, and the back and bottom of light sheet-iron, bent round, and nailed upon the edges of the wooden ends. The buckets are now attached to two leathern belts, $2\frac{1}{2}$ inches in breadth, at distances of two feet from bucket to bucket, by one rivet or a small screw and nut in each end of each bucket. The two belts, with their buckets, are then laid round the pulleys x at top and bottom, and connected at a proper degree of tension; and to prevent any inequality of motion in the two belts, it is well to attach two diagonal straps to them of about 4 feet in length. As the lower end of the chain of buckets passes under the level of the floor, a boarded cradling is there formed to collect any stray grains that may fall beyond the buckets, where, as they accumulate, they are taken up by the buckets in their transit through the cradle. The contents of the buckets are discharged as they turn over the upper pulleys x into the shoot z, from which they fall upon the feeding-board e.

1285. The clean elevators w w, fig. 1, Plate XXI., are formed after the same manner, except that the buckets are of smaller size, their breadth being only 10 inches, and depth 3 inches. They are sometimes formed also on a canvass web, but the principle is the same in all. The clean elevators discharge their contents, in the same manner as the first, into the shoot b' leading into the second fanners a'. The velocity at which such elevators move is usually from 150 to 180 feet per minute.

1286. *The Second Fanners.*—The position of the second fanners is subject to endless variety, arising from the arrangement of the machinery and the point from which the motion is taken to drive them. That which is here adopted a', fig. 1, Plate XXI., is one by which the motion is easily obtained; and in the case of a preference being given to hand-driving, the position is equally convenient. The more minute details of this sort of fanner will be also given under Barn Fanners.

1287. The ultimate utility of working the second fanners, and still more, as practised by some farmers, a third fanner, by the same power that is employed to thrash, is a question still unsettled. The operation of riddling, which is generally required for the grain as it comes from the clean-spout, has not yet been very satisfactorily performed by machinery, and to put it through the second and third time, without riddling, will seldom produce a perfect sample. The difficulty may be got over by removing the clean elevators from the spout and make them lift from the heap riddled by hand; but even were this done, there is a defect in the process, arising from inequality of blast, owing to the motive power, from inequality of feeding, not having at all times a uniform velocity, which is a circumstance not easily overcome. The most perfect system of dressing with the fanners is that where, water being the power, a small water-wheel is employed to drive the second and third fanners alone; and where water is abundant this may be practised simultaneously with the thrashing, or, if scarce, the dressing is performed as an after operation.

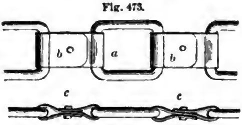
1288. An ingenious method of equalising the blast of thrashing-machine fanners was adopted by Mr Andrew Sharpe, Hilton, near Dunfermline, previous to the year 1835, for a description of which he received the Highland and Agricultural Society's silver medal. The invention consisted in placing a hinged flap, in form of a valve, in the wind passage of the fanners, occupying the entire width of the passage, the flap being adjusted to occupy a certain position when the fanners was emitting the due force of blast; but if this was increased by any acceleration of the motive power, the first effect of the acceleration was to increase the area of the wind-passage by raising the flap. The flap, by means of levers and rods, being placed in connection with a pair of light folding-doors attached to the eyes of the fanners, the same cause that produced the effect on the flap, tending to enlarge the wind-passage, produced at the same instant, through the medium of the levers and rods, a counteracting influence, by closing the folding doors, and thereby decreasing the aperture of the eyes, and, by consequence, the volume of air entering by them, thus tending to preserve a uniform intensity of blast. The principle of this apparatus seems to be sound, and there appears no reason to doubt that a due adjustment of them would effect a decided improvement in fanners driven by a variable power.

1289. *The Chain-gearing System.*—We have now described the thrashing-machine, as driven by wheel-gearing, in full detail; there remains only to say a few words on the method of chain-gearing. Fig. 2, Plate XXI., is an elevation of a machine fitted with chain-gearing. In this figure *a a* is the wall separating the corn from the straw-barn, *b b* the foundation-beams, *c* the framework of the machine, and *d* the feeding-board, exactly the same as in the toothed-wheel system; *m* and *n* are the spur-wheels intermediate to the power, and the great spur-wheel *e*. This last wheel having a velocity of 65 revolutions per minute, there is placed upon its shaft a chain-wheel of 10 inches, for the purpose of driving the feeding-rollers. A pitch-chain *f* is passed round this wheel, and also round one of the same diameter *g* on the driving-shaft of the feeding-rollers; this chain and wheel *g* give motion to the same train of gear as described in fig. 468, which can be proportioned as detailed under fig. 468. The mitre-wheels, however, are wanting, which in this mode of driving could only be of use for reversing the motion of the rollers (1244)—an operation which is often thought of little value—for if straw is once allowed to wrap around the rollers, it is easier to cut it off than to unwind it; this single chain then accomplishes the whole work of the feeding, and is perhaps the best and most simple method that can be adopted.

1290. The *Drum* is driven by a pinion *h*, a chain, under the circumstances, being inapplicable to the purpose.

1291. The *Shakers* are both driven by the chain *i i i* which passes over the wheels *k k* on the first and second shaker-shafts, and also over another wheel set upon the shaft of the spur-wheel *e*; and for the purpose of keeping a due degree of tension on the chain, a small movable tension-pulley *p* is applied. This provision for keeping the chain in a proper degree of tension is the more required in this particular arrangement, wherein the chain, in passing over the wheel of the first shaker, touches only a small part of its circumference, and, unless under proper tension, the chain would be liable to start over the studs of the wheel. The proportions of the shaker-wheels to that upon the shaft of the spur-wheel must be attended to in order to bring out the proper velocities, as given at 1276. It will readily occur to the reader, that the same results will be obtained by using two chains, and two chain-wheels on the shaft of the first shaker. In such arrangement, the first chain passes over the wheel on the main shaft of *e*, and also over one of those on the shaft of the first shaker. The second chain passes round the two wheels *k k*. The chain-gearing is extremely simple, and if made sufficiently strong, will work very satisfactorily; but unless attention is paid to due strength, and that all the links are properly adjusted to length, the chains are sometimes liable to failure.

Fig. 473.

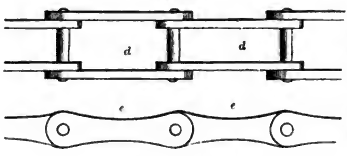


THE BUCKLE PITCH-CHAIN.

1292. *Pitch-Chains.*—Pitch-chains are of two kinds—the *buckle-chain* and the *ladder-chain*. The buckle-chain, fig. 473, is formed of links *a* of an oblong shape, forged and welded out of round iron; the strength of which, for shakers, may be $\frac{7}{16}$ inch diameter; these alternate with flat links *b* formed of the strongest hoop-iron, 1 inch in breadth; and these are folded in the form as represented by *c c*, which is the chain viewed edge-ways, the flat links being secured by means of one rivet passing through the three parts of the link.

1293. The ladder-chain is represented in fig. 474. In it the links are all of one size and strength, and, when formed, has the appearance as seen at *d d*, where they are arranged in pairs, inward and outward alternately, the pins or rounds passing through two links at each end, and riveted; *e e* is an edge view of this chain, the links being worked on one edge to the curvature of the wheel, and are in like manner curved on the opposite, for uniformity and lightness. This form of chain is the stronger and more durable, but at the same time the more expensive of the two; and both examples are on a scale of 3 inches to 1 foot.

Fig. 474.



THE LADDER PITCH-CHAIN.

1294. Numerous other forms of chain are employed in the practice of mechanics; but as they seldom or never come under the agricultural branch, it is unnecessary to do more than thus advert to them.

1295. *One-horse Thrashing-Machine.*—There is a diminutive form of thrashing-machine that merits notice—a one-horse machine. In some of our pastoral districts, where the proportion of arable land is so small as not to warrant the expense of a large thrashing-machine, these have been very successfully adopted. They are constructed with a small horse-wheel, generally overhead; and the motion is carried into the barn in the usual form, where a spur-wheel drives the drum-pinion at a velocity of 250 turns per minute. The drum is 27 inches long, and 30 inches diameter over the beaters: it strikes downward, and has a pair of feeding-rollers. There is neither shaker nor fan attached to the machine, and four people are required to carry on the process, the dressing being an after operation. With this little machine 12 bushels of oats can be thrashed in an hour; and the whole cost of it is about £20.

1296. *The English Portable Thrashing-Machine.*—We have now come to the English thrashing-machines, and the remarkable character which they present consists in their being portable. The English portable thrashing-machine is now most extensively employed in the southern parts of the kingdom, and apparently to good purpose. But while we grant this to the machine, we must demur to the practice which involves out-of-door thrashing. But it is to one member of the machine that we wish to direct attention, namely, the *drum*.

1297. It appears to us, in regard to the drum, that the English and the Scotch machines operate on different principles. In the Scotch, as is well known, the thrashing is performed by a process of beating, and the instrument acts over but a short space upon the grain undergoing the process, that is, while it is under the drum-cover, or about one-fourth the circumference of the drum-case; and even during a part of this progress, the cover is so distant from the beaters—about 3 inches—that little effect is produced upon the straw beyond a few inches from the feeding-rollers. There can be no doubt that, owing to this peculiar construction, when a stray ear of corn, or a sheaf-band, happens to enter root foremost, it is very likely to pass unthrashed, for the rollers have no hold of them; and they are so lightly pressed upon the beaters that we cannot be surprised at their passing in an imperfectly thrashed state.

1298. It has come under our observation, also, that, taking our machines as usually worked, and applying them to the thrashing of corn cut by the scythe, the work, from the same cause, is often imperfectly performed, mainly in consequence of many of the ears entering by the reverse end.

1299. Of late years many attempts have been made to improve our thrashing-machines, by improving the shaking apparatus, apparently forgetting that the shaker should have nothing to do beyond separating loose grains from the straw. The duty of the shaker is not to thrash; and when foul thrashing appears, it is the drum, not the shakers, that are in fault.

1300. Let us turn to the English machine, which had, till lately, nothing beyond a drum and feeding-rollers; and even the rollers can be left out. The drum, or, as we would call it, the *rubber*, though armed with what may be called beaters, does not, in fact, thrash by beating, but by rubbing the grain against a wire-grating, and in this lies its best qualities. The drum of this machine is a skeleton formed of two rings of cast-iron, similar to fig. 472, fixed upon an axle, and to these rings are fixed six beaters, lying parallel to the axle, forming a skeleton cylinder. Its diameter never exceeds 24 inches, often as low as 20 inches, and its length from 24 to 30 inches. It revolves within a concave, which embraces nearly three-fourths of its circumference, and is nowhere more distant from the beaters than 1¼ inch. The concave is nearly throughout an open trellis or grating, composed of plates and rods of iron and wire; and, to complete all, this drum makes from 600 to 800 revolutions per minute. In an apparatus of this kind it is impossible that an ear of corn, enter how it may, can escape unthrashed, or rather rubbed; for it will be evident, we think, from the description, that the machine operates by a process of *rubbing* out the grain. And, with all the defects that attend these machines, it must be granted to them that they thrash clean.

1301. Contrasting these machines, we see the Scotch one operating with a very heavy, and, from its general construction, sluggish cylinder, its beaters moving with a velocity of less than 3000 feet a minute, and the grain subjected to its influence over a space not exceeding 1½ foot; and when worked by four horses, thrashing at the rate of 26 bushels of wheat per hour, dressing included. In the English machine is to be seen a small and extremely light skeleton-cylinder, which, from its structure, must be easily moved, though its beaters move with a velocity of 4000 feet per minute, and the grain is subjected to its influence over a space of about 4 feet, and, when worked by four horses, thrashing at the rate of 36 bushels of wheat per hour, but not dressed, though in general very clean thrashed. The straw is perhaps a little more broken, which is sometimes unimportant.

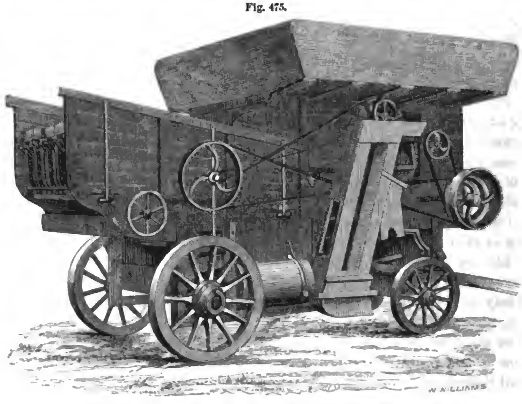
1302. *Dray's Two-horse Portable Thrashing-Machine.*—In Plate XXIII. we give views of a two-horse portable thrashing-machine, as manufactured by Messrs Dray and Co., of Swan Lane, London. Fig. 1 is a side elevation partly in section, showing the beater or rubber; fig. 2 a plan, and fig. 3 an end elevation. The machine is fitted with four small wheels, and is generally transported from place to place on the framing of the "horse-gear work," hereafter illustrated and described in Division Third, Section First, on Horse Power. The length of the machine is 6 feet, the height is 5 feet 8 inches, and breadth 4 feet 9 inches. The drum *a a*, fig. 1, 21 inches in diameter, revolves nearly in contact with the breast, or concave *b b b*. The drum-shaft carries a pinion *c*, 3 inches diameter, figs. 2 and 3, with which the spur-wheel *d d*, 25 inches in diameter, engages. To the spur-wheel shaft a coupling *e*, fig. 3, is fixed, this being connected with the driving-shaft of the "horse gear," hereafter described in the section on Horse Power. The drum *a*, fig. 1, is constructed of wrought-iron rings, and six square wood beaters, plated with iron; the concave or breast *b* is made of wood, with rough cast-iron plates and wire. The corn falls through the interstices as it is beat out by the action of the drum, while the straw passes on to the open wood-frame *f f*, fig. 3, on passing over which the corn remaining is further separated from the straw.

1303. *The Portable Combined Thrashing-Machine.* — In the "portable combined thrashing-machine," now so much used and so favourably known in England, the operation of dressing and separating are combined with those of thrashing and winnowing. In this combination, a satisfactory adaptation is met with, of the manufacturing-like arrangements and general economy of the Scotch thrashing system, to the avowedly good principle of the beater and concave of the English plan of operating, as just described and illustrated in Plate XXIII., figs. 1, 2, and 3.

1304. From a paper on "Barn Machinery," read by Mr William Waller before the "Institution of Mechanical Engineers," November 5, 1856, we learn that the first portable thrashing-machine on wheels, which was driven by the power of steam, was made in 1842 by Messrs Tuxford, the agricultural engineers of Boston. In this case the engine was in the same frame. The same firm brought out the first combined machine, in which the corn was dressed and separated, as well as thrashed and winnowed, early in 1844. Many firms are now celebrated for their manufacture of this form of machine—as Messrs Garrett, of Suffolk; Messrs Hornsby and Son, Grantham; Messrs Barrett and Exall, Reading; Messrs Clayton and Shuttleworth, Lincoln; and Messrs Humphrey, Pershore.

1305. *Garrett's Portable Thrashing-Machine.*—In fig. 475 we give a perspective view of a portable combined thrashing, finishing, and dressing machine, manu-

Fig. 475.



GARRETT'S PORTABLE COMBINED THRASHING MACHINE IN PERSPECTIVE

factured by Messrs Garrett and Sons; and in Plate XXIV. views of the same to scale, fig. 1 being a side elevation, fig. 2 a longitudinal section, and fig. 3 a plan. The extreme length of the machine is 17 feet 4 inches; the height 8 feet

4 inches; and breadth, including wheels, 7 feet 8 inches; the breadth of body being 4 feet 10 inches. The machine is supported on four wheels, the two front being 2 feet 9 inches in diameter—the two hind, 3 feet 9 inches.

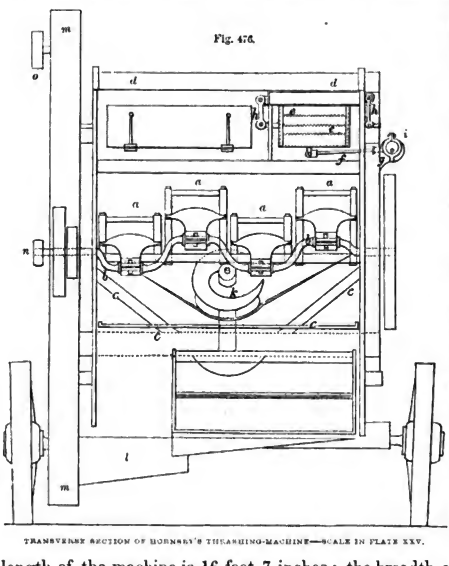
1306. The following is a description of the arrangement of its parts, the letters of reference being made to fig. 2, Plate XXIV. The man feeding the machine stands in the box or dickey *a a*, 17 inches deep, 20 inches long, and 16 inches wide. The sheaves are passed through the aperture *b b*, 2 feet 2 inches in width, and extending across the machine, as shown at *s s s* in the plan, fig. 3. It is then taken up by the drum *c c*, fig. 2, 1 foot 8¼ inches in diameter, and 4 feet 3½ inches long, and thrashed between it and the concave or breast *d d d*, which is adjusted by the link *e*. The straw then passes out from between the drum *c* and concave *d d*, at the point *f*, to the straw-shakers *g g*, *h h*, 8 feet 10 inches long, 12 inches broad, and 4 inches deep. In this form of shaker, known as the "cross-shaker," the boxes *g g*, *h h* move alternately up and down. The crank by which the vibratory motion is given to the boxes is placed in the centre of the length of the box; while the links—one of which is shown at *j j*, the length of link from centre to centre being 14½ inches—on which they vibrate, are placed at alternate ends. By this arrangement, the ends of each box have a different amount of rise or lift given to them: thus, the ends nearest the links rise a distance equal to the vibration of the link *j j* from its lowest to its highest point of movement, while the ends nearest the crank have a rise nearly equal to the throw of the crank; and as two of the four shakers have the links at the outer end, while the other two have their ends free, the straw, on passing out from the machine, is tossed up and down by the ends of the two free shakers, while it has a forward or progressive motion given to it by the other two, or those which have links, as *j j*, attached. Any corn remaining in the straw after it is passed on to the straw-shakers, is thus shaken out, and falls on to the vibrating screen *k k*, 7 feet 10½ inches long, and extending across the machine. This screen has a vibratory motion given to it by a crank *l*, through the medium of a link or lever *m m*, 4 feet 11½ inches long from centre to centre. The corn passes from the screen *k k*, and mixes with the greater bulk which falls from the drum and concave on to the second vibratory screen *n n*, to which the vibrating motion is communicated from the crank *l* by the link or lever *o o*, the length of which from centre to centre is 5 feet 11 inches. The cavings or short straws pass off at the end *p* of screen *n n*; while the corn and chaff are delivered to the winnowing-machine *q q*, from whence the chaff is blown by the action of a blower, the shaft of which revolves in bearings *r*, and which receives motion from the bevel-pinion *s*, driven by the bevel-wheel *t*. The corn is then passed to the "avelling" apparatus or hummeller *u u*, 7½ inches down, and extending across the machine. This is used for taking off the horns or avels from barley, and, in the case of wheat, for destroying any smut-balls, &c., that may remain among it. After passing through the "aveller," the corn is lifted up by the elevator, part of which is shown at *v v*, to the finishing dressing-machine *w w*, 18 inches broad and 11 inches deep; from which it passes to the rotatory grain-separator *x x*, 2 feet in diameter, furnished with a rotatory conductor. From this it is delivered into four spouts, one of which is shown at *y*, as "best corn," "seconds," "chobs," and "dross."

1307. In communicating the motion of the steam-engine which drives the machine to the various parts, the principal feature is the patent intermediate shaft *z z*, supported in the main frame of the machine, which takes the power off the engine, and distributes it to the drum and other parts. This arrangement gives a steadier motion to the various parts than when the power is, in the first case, laid on to the shaft of the drum or beater—which requires a high velocity—and from thence to the parts requiring slower motion.

1308. In fig. 1, Plate XXIV., *a a* is the main driving-pulley, 2 feet 8 inches diameter; *b b* the pulley of the drum or beater, 12 inches diameter; *c c* a small fly-wheel fixed on the shaft, $24\frac{1}{2}$ inches in diameter, which drives the shaker-cranks, fig. 2; *d d*, fig. 1, the pulley, 14 inches diameter, of the shaft which works the crank *l*, to give motion to the vibratory screens *k k*, *n n*, fig. 2; *e e*, fig. 1, the pulley, $11\frac{1}{4}$ inches in diameter, which gives motion to the fanner or blower of the winnowing-machine *q q*, fig. 2; *ff*, fig. 1, the pulley, 14 inches diameter, giving motion to the barley-aveller *u u*, fig. 2; *g g*, fig. 1, the pulley, 10 inches in diameter, which gives motion to the rotatory-screen separator *x x*, fig. 2; *h*, fig. 1, is the cover of the adjusting apparatus of the concave or breast *d d*, fig. 2; *i*, fig. 1, the pulley which drives the pulley *g g*—the shaft of this crosses the machine to the opposite side; *j j*, fig. 1, the gearing for driving the finishing dresser *w w*.

1309. In the plan, fig. 3, Plate XXIV., the same letters of reference as in fig. 1 denote the same parts. The pulley *j j*, 17 inches diameter, is that which gives motion to the shaft of the pulley *i i*, fig. 1; *l l*, fig. 3, the pulley, $13\frac{1}{2}$ inches diameter, which gives motion to the shaft of the gearing *j j*, fig. 1—this pulley being driven by a belt passing round the pulley *m m*, fig. 3, 9 inches diameter, fixed on the main shaft of the driving-pulley *a a*. The pulley *n n*, 19 inches diameter, drives, by means of a crossed belt, the pulley *o o*, 2 feet 2 inches diameter, fixed on the shaft of the shaker-crank, fig. 2; *p p*, fig. 3, is the fly-wheel on the shaft of pulley *d d*. The pulley *q*, 5 inches diameter, drives, by means of a crossed belt, the pulley *j j*, which works the elevator, of which the case is at *r r r*; *s s s* the drum, *b b* its pulley, *t* the dickey, *u u* the shakers, *v v* the delivery-spouts, *c c* the fly-wheel.

Fig. 476.

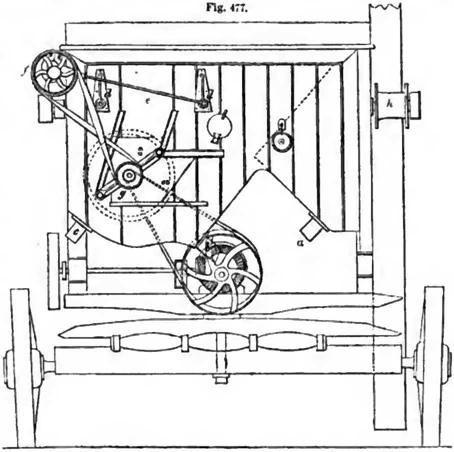


TRANSVERSE SECTION OF HORNSBY'S THRASHING-MACHINE—SCALE IN PLATE XXV.

1310. *Hornsby's Portable Thrashing-Machine.*—In Plate XXV. is given a longitudinal section of the thrashing-machine invented and manufactured by Messrs Hornsby and Sons, Grantham, Lincolnshire; in fig. 476 a transverse section; and in fig. 477 a front elevation, all drawn to the scale shown in Plate XXV.

1311. The extreme length of the machine is 16 feet 7 inches; the breadth over all, 6 feet 9 inches, not including travelling-wheels; including travelling-wheels, 8 feet 3 inches. The height from ground-line to top of elevator 9 feet $7\frac{1}{2}$ inches; the diameter of front travelling-wheels, indicated by the circle *a a* in Plate XXV., is 3 feet; of hind-wheels, indicated by the circle partly dotted *b b*, 4 feet.

Fig. 477.



FRONT ELEVATION OF HORNSBY'S THRASHING MACHINE—SCALE IN PLATE XXV.

1312. The following is a description of the various parts: The machine is fed at the dickey *c c*, Plate XXV., over the feeding-board *d* to the drum *e e* 22 inches diameter. The drum is composed of eight half-round malleable-iron buttoned beaters. The sheaves pass between the drum *e e* and the concave or screen *g g*, the distance between which and the drum is capable of adjustment. The straw is next passed to the straw-shakers *h h*, hung at the front end near the drum in links or swing-levers *i i*, and receiving an up-and-down motion at the back ends through the medium of the throw-crank *k*. There are four of these boxes, as shown at *a a a a*, in fig. 476, the upper surface being formed of a series of convex or angular openings, and furnished with spikes, as shown in Plate XXV. In fig. 476, *b b* is the throw-crank. The length of the shakers is about 11 feet 3 inches, the breadth about 15 inches, and depth 6 inches. The straw is passed along the length of the shakers *h h*, Plate XXV., and delivered at their back ends, while the corn, pulse, chaff, &c. remaining in the straw when passed from the drum falls through the slots or openings in the boxes of the shakers to the trough *l*, which is placed at an angle; the sides also being inclined, as shown by the lines *c c*, *c c*, fig. 476. From thence they are taken up an incline by the Archimedean screw *m m m*, the length of which is about 6 feet 3 inches, and diameter 15 inches, and delivered to the first riddles *n n*, in passing through which to the second riddles *o o* they are subjected to the action of the blast of air from the revolving-fan *p p*. The tailings pass off into the trough *q q*, in which a horizontal screw *r* revolves; this delivers the tailings to the Archimedean screw *s s*, which re-delivers them to the dressing machinery. By the action of the blast from the fan *p p*, the chaff and pulse are blown into the riddle *t t*, where they are cleaned, the chaff falling into the receptacle *u u*, and the pulse into the receptacle *v v*. The riddles *n n*, *o o* are suspended by the links *w w*, and the riddle *t t* by the links *x x*; they receive motion through the medium of connecting-rods *y y* and *z*, from eccentrics fixed on the shaft of the screw *r*.

1313. The good corn is passed from the lower riddle *o o*, Plate XXV., to the shaking-shoe *a′ a′*, from whence it is delivered to the elevator *b′ b′*, by which it is taken up to the barley awner or hummeller *c'*, where the wheat is freed from the husk, or, as the case may be, the beards or awns taken from the barley. The corn is at the same time propelled by the awner *c'* on to the riddles *d' d'*, shown at *e e*, fig. 476, and which receive motion by means of the connecting-rod *f* of the eccentric *g*; *h h* are the links by which the riddles *e e* are suspended. As the corn passes through the riddles *d' d'*, Plate XXV., it is subjected to the action of the blast of air from the fan *e' e'*, 18 inches in diameter. From the riddles *d' d'* the corn passes to a second barley-awner or corn-cleaner, shown at *i* in fig. 476, and which runs parallel to the side of the machine. The knives of this are arranged in a helical form, so as to propel the corn along to the screen *f' f'*, Plate XXV., from which it passes to a blower, where it receives the action of the blast of air from the fan *g' g'*, the light corn passing from the spout *h'*, or from the spout *a*, fig. 477—the best corn from the spout *c*, fig. 477, and the screenings from the screen *f' f'*, Plate XXV. The screen *f' f'* is suspended from the links *d d*, fig. 477, and receives its vibrating motion by means of the connecting-rod *e*, of an eccentric fixed on the end of the shaft of the pulley *f*, which drives the pulley *g* of the fanner *g' g'*, Plate XXV. In fig. 476 *k* is the screw corresponding to *m m* in Plate XXV., *l* the shaking-shoe corresponding to *a' a'*, and *m m* the elevator, corresponding to the elevator *b' b'*, *b' b'*, Plate XXV.

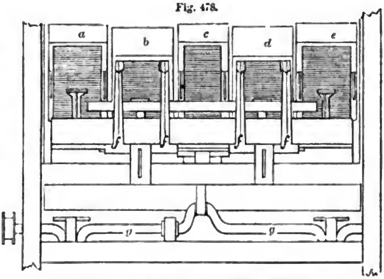
1314. *Clayton and Shuttleworth's Fixed Thrashing-Machine.*—In Plate XXVI. we give two views of a *fixed* combined thrashing-machine, manufactured by Messrs Clayton & Shuttleworth, of Stamp End Works, Lincoln—fig. 1 being an elevation of the corn-delivery side of the machine, and fig. 2 a longitudinal section. The extreme length of framing is 14 feet 3 inches, breadth 5 feet 3½ inches, and height 9 feet 11½ inches.

1315. The following is a reference to the letters in fig. 2, Plate XXVI.: *a a* is the dickey, 25½ inches deep, 20 inches wide, and extending across the machine; *b* the mouth of the machine, 25½ inches wide, and extending across the length of beater-shaft, into which the sheaves are fed to the drum or beater *c c*, 22 inches in diameter, and 4 feet 6 inches long. The drum carries beater-plates on its periphery; and by the action of these on the sheaves while being drawn over the concave or breastwork *d d*, the grain is beaten from the ear. The concave *d d* is adjusted by set-screws at *e e*. The straw is passed from the drum and concave into the chamber *f f*. The straw, with such corn in it as may have passed from the drum and concave, is thrown on to the straw-shakers *g g*, *h h*, of which *g g* is 8 feet 11 inches long, and *h h* 8 feet 3 inches; the depth of these at one end is 5, and at the other 3½ inches. There are five of these boxes—of which there are four 10½ inches wide, and the fifth, or central one, 8½ inches. Of these five boxes, the second and fourth have two links, one of which is shown at *i i*, the length of which, from centre to centre, is 14 inches. The inner ends of the other three shaker-boxes, one of which is shown at *g g*, are prolonged beyond the ends of the other two, as *h h*, to admit of the throw of the crank *k*, which gives them motion, and are attached to a cross-bar *j*, extending across the machine, and carried by two links outside the framework.

1316. In fig. 478 we give a part of end elevation at straw-shaker end, in which *a b c d e* are the five shakers, of which the second and fourth, *b* and *d*, are provided with links *f, f, f, f*. The grain which is shaken out of the straw by the action of the straw-shakers, falls on to the shock or shogging-board *l l*, fig. 2, Plate XXVI., suspended by the links *m m*, and to which a vibratory motion is given by the crank at *o* (*g g*, fig. 478), through the medium of the lever or link *p p*, 4 feet 4½ inches from centre to centre.

1317. To the riddle-board *q q*, fig. 2, Plate XXVI., the whole of the grain and chaff is brought to be dressed, which falls directly from the drum and concave, guided by the board *r r*, and from the straw-shakers *g g*, *h h*. This riddle—which is worked by the links *s s*, 3 feet 10½ inches from centre to centre—is of a coarse mesh, so as to take off the cavings or short straw, those being passed off at the end. The grain passes through upon the board *t t*, below the riddle *q q*, on to the second riddle *u u*, having a finer mesh. The grain here meets a blast of air from the blower or fan *v v*, 22 inches diameter, which drives off the chaff through the opening *w*. The grain next falls on to the third or fine riddle *x x*, through which it passes—small stones, &c., being passed over the end—to the spout *y*, which delivers it to the shoe of an "elevator." From this it is taken up by the "cans" and delivered to the barley "aveller" or "hummeller" *z z*, into which the corn is passed. From this it is delivered to sacks, should it not be required to be dressed. In ordinary circumstances, however, it passes from the aveller *z z* again to the riddle-board *q q*, where the same process is again gone through. It is from the last riddle, *x x*, delivered to the shoe *a a* of a second elevator *b b*, fig. 1, Plate XXVI., which delivers it to the chamber *c* of the separator. In passing out of the chamber *c*, as shown by the arrow, a powerful blast of air from the fan or blower *d d* projects all light grain through the shoot *e e*, from whence it is taken out by the spout *f*. The heavy grain passes through a revolving screen placed at an angle in the case *h h*. This screen is composed of different meshes, and passes the grain to different spouts—the small grain to that marked *i*, the larger to *j*; the best corn only passing completely through the screen, and being delivered at the spouts *k k*.

Fig. 478.



PART ELEVATION OF SHAKER END OF THRASHING-MACHINE—SCALE ½ INCH TO THE FOOT.

1318. The peculiar arrangement of this corn-dressing screen will be described in a succeeding paragraph, and illustrated in Plate XXVIII.

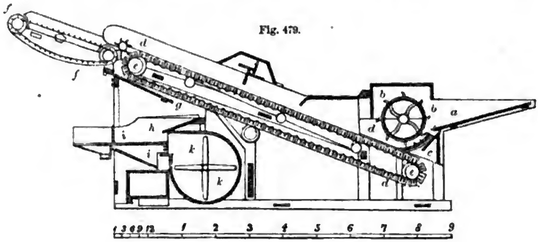
1319. In fig. 1, Plate XXVI., the other parts not referred to in the above description are *m* and *n*, the set-screws by which the concave *d d*, fig. 2, is adjusted; *o* the suspending links for the shock-board *l l*, fig. 2; *p p*, *p p* the links for the riddle-boards *q q*, fig. 2, and *q q* the links for the straw-shakers *g g*, fig. 2; *r r* is the barley-aveller, and *s s* the end of the riddle *q q* in fig. 2.

1320. The thrashing-machines illustrated in Plates XXIV., XXV., and XXVI., are suited for large farms, where steam-engines of from six to eight horse-power are employed.

1321. *Dray's Four-Horse Portable Thrashing-Machine.* — In fig. 4, Plate XXIII., we give the section of a thrashing-machine to be worked by a four-horse engine only, this form being introduced by Messrs Dray, Swan Lane, London. The length of the machine is 12 feet 8 inches, the height 7 feet 3 inches. The following is a reference to the various parts: *a* the mouth, 16 inches wide, by which the grain is fed to the drum *b b*, 19 inches in diameter; *c c* the concave, adjusted by the set-screw *d*; *e e* the straw-shakers, four in number, suspended at the outer ends by links *f f*, and having a vibratory motion given to them by cranks, as at *g*; *h h* a conducting-board, which leads the grain passing from the shakers *e e* and concave *c c* to the riddle *i i*. The board *h h* and riddle *i i* are worked by the crank *j j*, and the links or levers *k* and *l*. The first riddle *i i* takes out the cavings or short straw, the corn and chaff pass on to the board *m m*, and from thence to the second riddle *n n*, where it meets the blast from the fan or blower *o o*, 19 inches in diameter, by which the chaff is blown out. From the riddle *n n* the grain passes to the board *p p*, on to the third riddle *q q*, from which it is delivered by the spout *r* to the shoe of an elevator, which delivers it through a spout placed at a sufficient elevation to admit of a sack being set below it.

1322. *American Thrashing-Machine.*—As a machine presenting some features of novel arrangement, we give, fig. 479, a section of an American thrashing-machine. The sheaves are fed by the inclined feed-board *a*; *b b* is the drum, *c* the concave

Fig. 479.



SECTION AND SCALE OF AN AMERICAN THRASHING-MACHINE

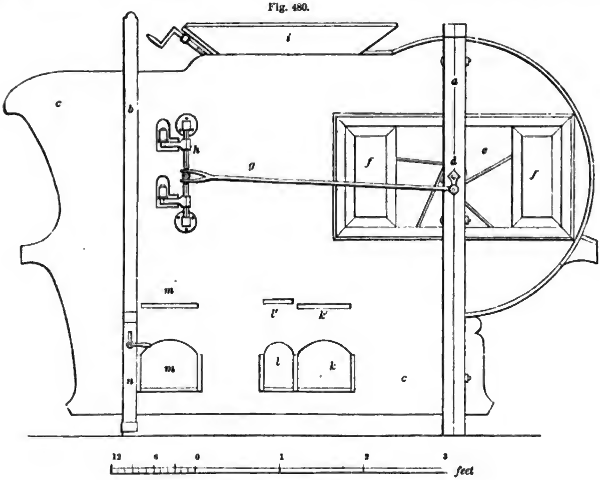
or breast; the grain and straw are delivered to the straw-shakers *d d*, revolving as an endless web on two rollers or drums *e e*; the straw is taken off by the second endless web *f f*; the grain is passed down the shoots *g* and *h* to the riddles *i i*, where it is met by the blast from the fan *k k*, and delivered by a spout below.

1323. *Barn-Fanners.*—The fanners referred to in the description of the Scotch thrashing-machine is the common winnowing-machine or fanners, and is here represented in figs. 480, 481, and 482. The first figure is an *elevation*, the second a *longitudinal section*, and the third a *transverse section*. These figures exhibit in detail a fanner that is considered to be of the most approved construction, both for cleaning and separating the various qualities of grain. A scale of feet applicable to all the figures is attached to fig. 480.

1324. The principle on which the blast of the fanner is produced being so well known, it appears unnecessary to do more than merely to say, that it is produced by the quick revolution of a light four or five vaned fan within a case, the air being inhaled through central openings in the sides of the case, and discharged with considerable force by a lateral opening in the curved side of the case, through which it is discharged upon the grain as it falls from a hopper. The grain thus subjected to the effects of a strong current of air undergoes a mechanical separation and distribution; and in this machine these separations extend to five divisions: 1, the sound and best grain; 2, an inferior quality in respect of individual bulk of the grains; 3, extraneous small seeds; 4, light grain, and grain with husks attached; and, 5, the chaff. These separations go on simultaneously, and the proceeds of the different divisions are each collected separately.

1325. The machine, in its dimensions, measures 6 feet 9 inches in extreme length, 4 feet 9 inches in height, and in breadth 1 foot 9 inches. In the elevation, fig. 480, the following parts are exhibited: The framework, formed usually of hardwood, consists of the principal frame *a*, which is usually made double,

Fig. 480.

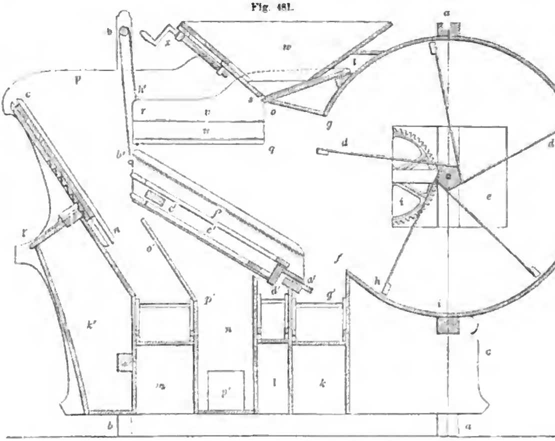


THE ELEVATION AND SCALE OF DRESSING-FANNERS.

or in halves, for the convenience of removing the outward half of the fan-case, and of the back-frame *b*. The distance at which these frames are placed apart is 3 feet 8 inches, and the axle of the fan has its bushes in the line that joins the principal frame. The side-boarding *c c* is of $\frac{3}{4}$-inch deal: in laying it out, the centre of the fan *d* is 3 feet from the bottom, and the radius of the fan is 1 foot 6 inches. The air-ports *e* are furnished with the sliding-panels *ff*, by which the admission of the air, and ultimately the force of the blast, can be regulated. The crank *d* has a radius of $1\frac{1}{2}$ inch; and the connecting-rod *g* communicates motion to the double or bell-crank spindle *h*, whose office it is to move the riddle-frame. The hopper *i* receives the rough grain, and the spouts *k l m* deliver respectively the first, the seconds, and the light grains, after separation in the machine; but, as it would be inconvenient to deliver these all at one side, there are corresponding sliders *k' l' m'*; and each side being provided with spouts and sliders, the sliders are shifted so as to cause the three qualities to be delivered, two on one side, and the third on the opposite side. The slot-bar *n* is for the purpose of adjusting the length of the fourth foot of the machine to any inequalities of the barn floor.

1326. Fig. 481 is the longitudinal section, where *a a* is the main frame, *b b* the back-frame, and *c c* the side-boarding; *d d* is the fan with its five vanes, and *e* the air-port. The fans revolve within the circular case *f g h*, the space *f g* being open for the discharge of the air; the position of the point *f* is determined by taking the chord of an arc *h i* = 12 inches, and *h f* a tangent to the curve at the point *h*. Then, with a horizontal distance of 15 inches from the diameter *a i*, cut the tangent in the point *f*, and drawing *f k* parallel to *a i*, and the

Fig. 481.



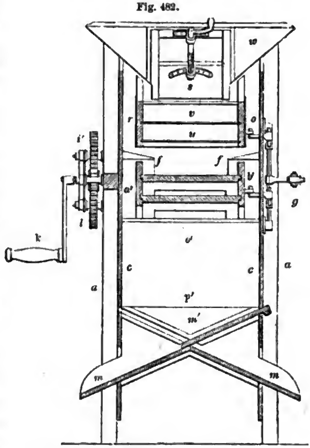
THE LONGITUDINAL SECTION OF THE DRESSING-FANNERS.

position of a side of the spout, *k*, is given. The width of the spout *k* is 7½ inches, that of *l*, 4 inches, and of *m* likewise 7½ inches, leaving the intermediate space *n′* 8 inches. The opening *f g* in the case for the discharge of the blast is 20 inches; and the funnel-board *g o*, 9 inches in breadth, is so placed that, if produced, it would meet the tangent *h f*, when also produced, in the line of the upper edge of the side-boarding at a point *p*. The shoe and riddle-frame, of which *o q r s t* is one of the sides, has the shoe *s t*, 13 inches in breadth, nailed upon the under edges of the two sides, sloping at an angle of about 18°, while that part of the sides that form the riddle-frame lies horizontally, and is 6½ inches in depth. It receives two riddles, slid into the grooves *u* and *v*, and the entire frame plays horizontally on a pivot in *t*. The hopper *w* is 28 inches square at the top edges, the side sloping inward to 9 inches in width and 7½ inches in length, where it meets the shoe, and is fitted so as just to let the shoe vibrate freely below it. A sluice *o* is fitted to the front of the hopper, and moved by the screw-winch *x* to regulate the feed. The sieve-frame *a′ b′* is 28 inches in length and 5 inches in depth; the two sides are connected by the bars *c′* and *d′* at a width of 15 inches over all, being the same breadth as the riddle-frame. This frame is also provided with two sets of grooves *e′* and *f′*, which receive the sieves; and the frame is supported in front on a pivot at *a′*, or, as in most cases, it is produced to *g′*. Both frames are supported behind by the chains *b′* and *h′*, attached to the stretcher-rod *b*. The toothed wheel *i*, seen in part through the air-port, is turned by the winch-handle *k*, seen in fig. 482, and acts upon a pinion fixed upon the axle of the fan. The proportions of the wheel and pinion are 4½ to 1, the fan making from 212 to 220 revolutions per minute. The space *k′*, fig. 481, is a locker in which the spare riddles are kept, *l′* being a lid that opens into it; *c n* is a slider that can be raised or depressed to catch the light grain, while it allows the chaff to pass over. The sieve-frame *a′ b′* is furnished with two wire-cloth sieves; the upper one has 9 meshes in the inch, the lower 7 meshes.

1327. The full complement of riddles for the riddle-frame is six, of which two only can be employed at one time. Their meshes are, for wheat 5 in the inch, for barley 4 in the inch, and for oats 3 in the inch. The slap-riddles are $\frac{3}{4}$ inch, and 1 inch in the meshes.

1328. Fig. 482 is the transverse section; *a a* the frames, *c c* the side-boarding; *m m* are the light spouts, corresponding to *m* of figs. 480 and 481; *m* are the sliders to change the direction of the discharge, and *o′ p′* is the sloping division *o′ p′* of fig. 481. The sieve-frame, with its two sieves, is contained between *a′* and *b′*, fig. 482; and *f f* are two flaunch-boards, sloping over the sieve-frame, to direct the grain upon the sieve. The riddle-frame, with its riddles *u* and *v*, are contained between *r* and *o*; and *w* is the hopper, with its sluice *s*. The end of the connecting-rod *g*, fig. 480, is seen at *g*, as jointed to the bell-cranks that shake the riddles and sieves by their attachment at *b′* and *o*; *i′* is the toothed wheel, with its winch-handle *k*, and framework *l*, by which the fan is impelled.

Fig. 482.



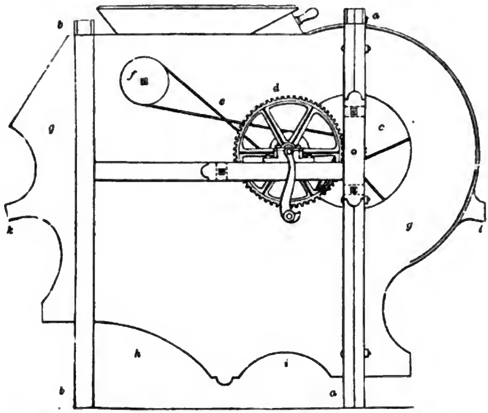
THE TRANSVERSE SECTION OF THE DRESSING-FANNERS.

1329. When these fanners are in operation, the blast is sent through the tunnel *f g o b′*, fig. 481. Its chief force is directed upon that end of the riddles *q o*; and as the grain falls from the hopper upon that end of the riddles, the lighter chaff is immediately blown off beyond the point *c*. The remainder, with the grain, will be passing through the riddles towards the sieve; and during this stage, any remains of chaff are blown off, and the light grain and seeds are blown beyond *b′*. The blast not having power to carry them over *c*, they fall down between *c* and *b′*, and are discharged at the *lights* spout *m*, (and *m*, fig. 480), at the same time the heavy grain and seeds fall upon the upper sieve *f′*, when all the plump full-sized grains roll down over this sieve, and are delivered at the *first* spout *k*, (and *k*, fig. 480). These grains, together with other seeds, whose specific gravity exceeded the *lights*, but whose bulk was under that which the upper sieve is intended to pass, fall through the meshes, and are received upon the lower sieve *e′*; upon this the grain so received rolls down and is delivered through a small opening at the foot of the sieve *e′* into the chamber of the *seconds* spout *l*, (and *l*, fig. 480). The smaller seeds, such as those of the wild mustard and others, being too small to be retained even upon this sieve, fall through it, and are received into the chamber *n′*, from which they are removed at convenience through the aperture *p′*, which is closed by a sliding-shutter.

1330. The usual price of this barn-fanner, with its riddles and sieves, is £9, 9s.

1331. *The Finishing Fanners, or Duster.*—This fanner, fig. 483, is of simpler construction than fig. 480. On many occasions it may take its place; and, from its lightness of working, may be always employed for giving the finish after hummelling, or when grain has lain any time in the granary. This, in regard to blast, is constructed on the same principle as the other; but in its details is much simplified. Fig. 483 is an *elevation*, in which the framework is similar to fig. 480, but its over-all dimensions are smaller, the extreme length being

Fig. 483.



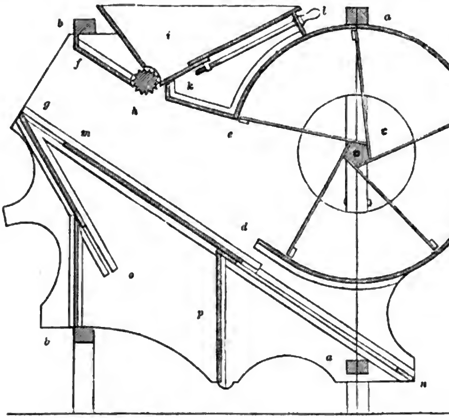
THE ELEVATION OF THE FINISHING-FANNERS OR DUSTER—SCALE SAME AS IN FIG. 480.

5 feet 8 inches, the height 4 feet 8 inches, and the width, as in the other, 1 foot 9 inches. The main frame *a a* is again made in halves, and the back frame *b* is placed at 3 feet from the main. The diameter of the fan is 3 feet, and of the air-port *c* 16 inches. The wheel *d*, and its pinion on the axle of the fan, are in the same proportion as in fig. 480; but on the axle of the wheel, a pulley, of 5 inches diameter, is mounted, which, by means of a cross-belt *e*, drives the pulley *f*, of the same diameter, placed upon the axle of a feeding-roller. The side-lining *g g* is formed to the taste of the maker, except in that part which forms the fan-case, and in the parts *h* and *i*, which are cut away to afford more ready access to the *lights*, and to small seeds that may have been separated: *k* and *l* also are handles by which it may be lifted.

1332. Fig. 484 is the *longitudinal section*, where, as above, *a a* and *b b* are the cross-rails of the frames, and *c* the air-port. In this machine the blast is sent directly through an open tunnel, the opening *d e* being 17 inches, and *f g* 11 inches; the latter being continued outward from the feeding-roller *h*, which is so placed as not to offer any obstruction to the current. The hopper *i* is furnished with a slider *k*, which is adjusted to the requisite feed by the screw *l*; and the sole of the tunnel from *m* to *d* is a solid board, while the shoot from *d* to *n*—the point of discharge for the *firsts*—is a wire-sieve. The opening between the case *d* and the sole is 3¼ inches, and the slope is an angle of 35°. That part of the sole *m d*, and the board *g o*, are both fitted to slide up or down to temper the division of the *lights*, should any of them remain; and *p* is a division separating the lights from the small seeds.

1333. Fig. 485 is the *transverse section*: *a a* are the frames, *b* is the winch-handle, *c* the wheel-framing, and *g* the wheel; *f* is the pulley of the feeding-roller, *h* the roller, and *i* the hopper. Of the interior parts, *p* is the division

Fig. 484.

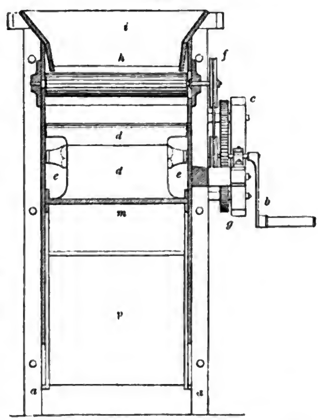


THE LONGITUDINAL SECTION OF THE FINISHING-FANNERS OR DUSTER.

under the sole, *m* is the sole as seen below, and *d d* are the vanes of the fan, *e e* being its axle.

1334. In operating with this fanner, the grain is taken from the hopper by the revolution of the feeding-roller; and as it falls perpendicularly in a thin sheet, is intercepted by the blast under the most favourable circumstances. All such chaff and dust as yet remain amongst it is blown over the back-board *g*, fig. 484; the light grain that may have remained is separated also, and falls between *g* and *m*, down the spout *g o*; the remainder runs down the sole *m d*, and in passing from *d* to *n*, should any small seeds yet remain, they are intercepted, and fall through the screen *d n*, while the good grains pass on and are delivered at *n*.

Fig. 485.



THE TRANSVERSE SECTION OF THE FINISHING FANNERS OR DUSTER.

1335. The price of this fanner is £6, 15s.

1336. *The Thrashing-Machine Fanners.*—The thrashing-machine fanners differ so little in their essentials from fig. 480, that it appears unnecessary to give a figure of it. The width for a 6-horse-power machine ought to be considerably more than the common fanners—not under 24 inches, nor is it requisite that it should exceed 30 inches. The fan is of the same diameter, and the first spout stands in the same relation as described in fig. 481, but should be 20 inches distant from the vertical line passing through the centre of the fan, and 9 inches wide. There is no spout corresponding to the *seconds* of fig. 481; but the foul-spout takes the place of the lights, and is 11 inches wide; the distance between them should be 22 inches. The riddles and sieves of fig. 481 are entirely left out, and in their place is a simple shoe, of 2 feet 10 inches in length, with a sheet-iron bottom, which is perforated all over with 1-inch holes at ⅜ inch apart. This is placed under the great hopper, and is agitated by a connecting-rod from a crank on the fan-axle, in the same manner as exhibited in fig. 480. The extreme length of the machine-fanners should be 8 feet, and their height 4 feet 10 inches.

1337. *Dray's Corn-Dressing Machine.*—In Plate XXVII. we give two views of the corn-dressing machine manufactured by Messrs Dray and Co., of Swan Lane, London Bridge; fig. 1 being a side elevation, and fig. 2 a longitudinal vertical section.

1338. The principal features of this machine are—1, By using the straight-forward throw to move the riddles, the whole width of the machine is made available; whereas, in other machines, one-third of the machine is occupied by the cross movement of the riddles. 2, The same movement is made to answer the purpose of a feed-roller, and it supersedes it, as spiked rollers will frequently clog up in roughing. 3, The extreme simplicity of the machinery required to move the riddles and screen causes but little friction, and therefore takes but little power.

1339. The motion is given to the machine by the winch-handle *a*, fig. 1, on the shaft *b*, on which is keyed a spur-wheel *c*, 15 inches diameter, gearing into a spur-pinion *d*, 2½ inches diameter. This pinion *d* is carried by the fan-shaft *e*, supported by brass bearings on the frame of the machine. On the extreme ends of the shaft *e* are keyed two eccentric plates *f*, 3⅜ inches diameter, from which the motion is conveyed by connecting-rods *g*, 22 inches long from centre to centre, to the vibrating-rods *h h*, 19 inches long; from the top and bottom of *h* are hung the riddle-case *k k*, and screen *l l*, fig. 2. The screw *i* is that by which the elevation of the riddle-case *k k*, fig. 2, is adjusted. The adjustment of the screen *l l* is obtained by the chain *j*. The slide *m*, fig. 2, opens and shuts off the feed. On passing from the hopper *o o*, the corn is carried past the slide *m* along the coarse riddle *p*, which carries off all stones, cavings, &c.; it next falls through this on to the second riddle *q*, which carries off knottings, these passing through the spout *r r*. The corn then falls on to the conducting-board *s*, and from thence to the screen *l l*, where the light corn and seeds are separated; the good corn being delivered at *t*.

1340. When the dressing is required to be more thoroughly done, the board *u* is turned down so as to prevent the feed-board *n* taking the corn in too fast. The inclination of the riddles *p* and *q* which vibrates on the pivot *v*, is regulated by the adjusting-screw *i*; *w* is one of the five fans, and *y y* are handles by which the fanners are removed from place to place, being projecting parts of the lining. In fig. 1 *i* is the adjusting-screw as *i* in fig. 2, *k* the rough spout as at *r r*, *l* the good-corn spout as at *t*, fig. 2, and *m* the store for riddles.

1341. *Palmer's Rotatory Corn-Separator.*—In Plate XXVIII. we give different views of Palmer's patent rotatory corn-separator, to which we have already alluded in par. 1318, as being used in Messrs Clayton and Shuttleworth's thrashing-machines. The peculiar feature of this rotatory corn-separator or screen, is the employment of longitudinal divisions or partitions of iron or steel, set side by side in the interior of a revolving cylindrical screen or sieve of the ordinary character. These partitions are set at such a distance apart, that, as they rotate, they carry the grain up the side of the screen or cylinder, but not so far as to turn it over or round the centre. As the grain enters the elevated end of the screen, the partitions tend to distribute it over the inner periphery, and to return a larger amount of it in contact with the wire-work of the screen than is due to specific gravity, or to the momentum of the revolving-screen. The partitions, also, as they are carried round by the rotatory cylinder, dip into the corn lying in the lower part of it, and by their rubbing against the corn tend to arrange the individual grains in the direction of the length of the meshes of the cylinder, and thus to facilitate their escape from the screen.

1342. In Plate XXVIII. we give various views of the separator, drawn to a scale of 1 inch to the foot. Fig. 1 is a longitudinal vertical section; fig. 2, half of the end elevation, partly in section; fig. 3 an edge view of a few of the partitions; and fig. 4 a front view of a single partition. In fig. 1, *a a* is the framework of the machine; *b b* the central shaft, or axis of the screen *c c*, receiving motion through the medium of the bevel-gearing *d e*. Motion may be given to the rotatory screen by means of a winch-handle fixed to the upper extremity of the shaft *b b*. The cylinder or screen *c c* is composed of wire wrapped helically round longitudinal rods, these being riveted at their extremities to rings *f f*, *g g*, which are connected by radial arms, shown at *a a*, fig. 2, to the central shaft *b b*, fig. 1. The meshes of the cylindrical screen *c c*, fig. 1, are composed of wire of four different gauges, the finest being at the feeding end *g g*, the coarsest at the discharging end *f f*. Attached to the radial arms *a a*, *a a*, fig. 2, are two longitudinal bars, one of which is shown at *b b* in fig. 2, and at *h h h* in fig. 1. These extend from end to end of the cylindrical screen *c c*, fig. 1, and are fixed at opposite ends of the shaft *b b*. From these arms, bars *e*, fig. 2, project, and carry at their extremities the partitions *d d*, *d d*. These partitions, *d d*, *d d*, are arranged side by side at a distance of $1\frac{1}{4}$ inch from each other, as shown in fig. 3, and the forward end of every alternate partition is set forward in advance of its neighbour. By this arrangement, all the ends of the partition do not come into contact with the grain at the same moment, and their rubbing action is thereby facilitated. In order to keep the meshes clear, a steel-wire brush *f*, fig. 2, is applied to the screen, being connected to the framing by the standards *g g*, and is capable of being adjusted by the lever *h*, and screw *i*. Messrs Reeves, of Bratton, Westbury, who manufacture this screen in its separate or portable form for the patentee, give the wires of this brush a bent form; this imparts to them an elasticity which greatly facilitates the cleaning of the meshes.

1343. The corn to be cleaned is fed to the cylindrical screen *c c*, fig. 1, by the hopper *i i* (part only of which is shown in the figure); below the cylinder, corresponding to the positions of the different meshes of which it is composed, shoots, *k l m n n*, are placed to conduct the various products of the screening operation to suitable receptacles, as *o p q*. By the shoot *k*, the small seeds and dirt separated by the first division of the screen is delivered to the receptacle *o*; by the shoot *l* the thin corn is delivered to the receptacle *p*; by the shoot *m* the tail corn is delivered to the receptacle *q*, while the largest and best corn is delivered to the spout *n n*. At the end of the cylinder *c c*, a shoot *r r* is provided to receive poppy-heads and other bulky substances which will not pass through the meshes of the screen *c c*: these, as they are delivered from the end of the cylinder to the shoot *r r*, are carried away to a suitable receptacle.

1344. *The Hummeller.*—The hummelling of barley is a process that, in many cases, is essential to the marketable condition of that grain, and it is effected in many different ways. In some cases the thrashing-machine itself is made the hummeller, by employing a fluted cover to the drum; in others, without this addition, the barley is shut up in the drum-case for a few minutes while the drum is revolving, as recommended by the Rev. Dr Farquharson, Alford.*

1345. Another method is with a conical receiver, within which a spindle, carrying a number of cross arms, is made to revolve, and the grain passes through this machine, lying nearly in a horizontal position, before entering the fanners. This form of the hummeller was brought forward by Messrs Grant, Grantown, Banffshire,† and with some modifications,—which are, however, very important ones, and give a new character to the machine,—a hummeller similar to that is now the most approved form, the case being made cylindrical, and its position vertical. Instead, also, of the grain passing loosely through the cylinder, an essential characteristic of the improved machine is, that the cylinder shall be always full of grain.

1346. *The Cylinder Hummeller.*—The cylinder hummeller, figs. 486 and 487,

Fig. 486.

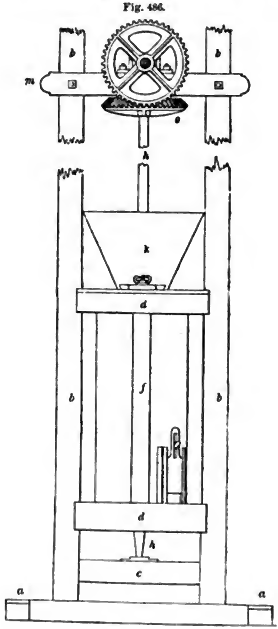
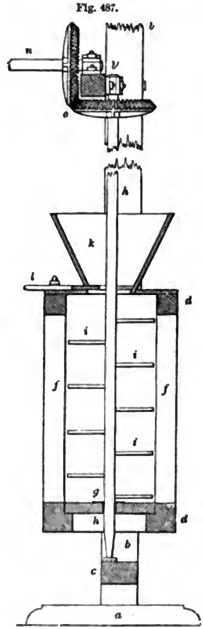


Fig. 487.



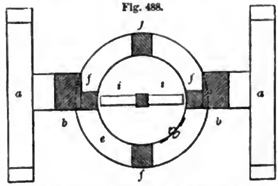
12 6 0 1 2 feet

THE ELEVATION AND SECTION OF THE CYLINDER HUMMELLER.

* *Prize Essays of the Highland and Agricultural Society*, vol. xiii. p. 66. † Ibid.

consists of a cylindrical case of wire-cloth, having an upright iron spindle revolving within it, armed with a number of flat thin blades of iron, kept in revolution at a high velocity. The grain is admitted through a hopper at top, keeping the cylinder always full, and is discharged through a small orifice at bottom, the degree of hummelling depending upon the area of this orifice. Fig. 486 is an elevation, fig. 487, a vertical section, and fig. 488 a plan of this hummeller, the same letters marking corresponding parts in each. The sole-frame *a a* rests on the floor of the corn-barn; *b b* are two strong posts rising from the former, and secured to the beams of the floor above; *c* is a bridge-tree which supports the foot of the spindle *h*; two rings of wood, *d d*, whose internal diameter is usually 10 inches, but varying according to the power of the machine, are supported by the uprights *f f*, making the height of the cylinder 2 feet 3 inches. It is lined with wire-cloth, of 10 or 12 meshes in the inch, and placed between the posts *b b*, and is furnished with a bottom *g*, which just admits the spindle *h* to pass through, and having a thin shield on the spindle, over the opening. The spindle is $1\frac{1}{4}$ inch square; the blades *i i*, of which there are two rows, 5 and 4 in a row, are 2 inches in breadth and $\frac{3}{8}$ inch thick, riveted into the spindle; or the blades may be cruciform, with an eye in the centre, through which the shaft passes. The hopper *k* may be either formed round the spindle, as in the figures, or it may stand to one side; and it may be furnished with a slider *l* to regulate the feed, though this is virtually done by the contraction or enlargement of the orifice below. For want of space here, the figs., 486 and 487, are represented broken off; but *m* is a bridge-piece bolted upon the posts *b b*, to support the head of the spindle at *b′*, and also the end of the horizontal shaft *n*; the spindle *h* and shaft *n* carry the mitre-wheels *o* that give motion to the spindle. The spindle requires to have a velocity of 300 to 400 per minute, and the motion may be conveyed in various ways, suited to the general arrangements of the machinery. In the present case, it is brought at once from the great spur-wheel by a pinion of the same size as that of the drum, the pinion occupying the position of the dotted circle *d′* in fig. 1, Plate XXI.; and its shaft is supported on a bracket appended to the beam *c* of that figure, at the one end, while the other has a bearing in the wall that separates the barn from the engine-house.

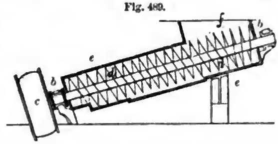
Fig. 488.



THE PLAN OF THE CYLINDER HUMMELLER.

1347. *Clayton and Shuttleworth's Hummeller.*—The form of "hummeller," "awner," or "aveller," used in the English thrashing-machine, as that of Messrs Clayton and Shuttleworth, is illustrated in fig. 489. A shaft *a*, resting on bearings *b b*, and set in motion by the pulley *c*, is provided with a set of knives *d d*; the whole revolving in a casing *e e*, set in an inclined position. The grain enters at *f*, and its passage down the casing *e e* is further facilitated by the knives being set in a spiral form on the shaft *a*. The shaft *a* should make from 400 to 500 revolutions per minute.

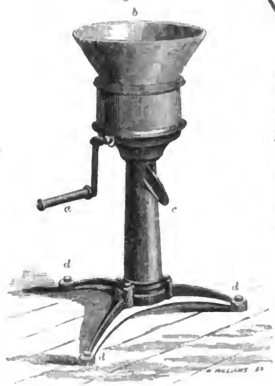
Fig. 489.



SECTION OF CLAYTON AND SHUTTLEWORTH'S HUMMELLER.

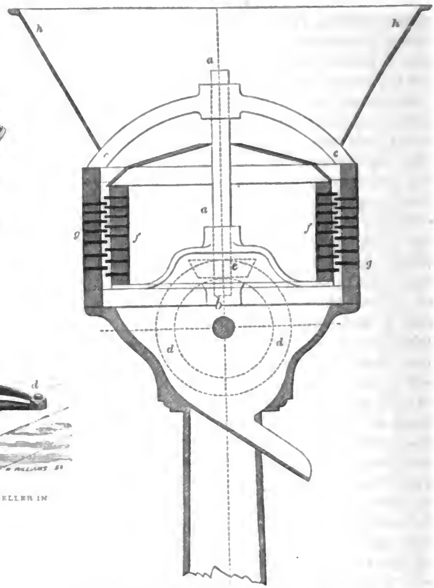
1348. *Ransome and Sims' Hummeller.*—In fig 490 we give a perspective view of an exceedingly compact and well-constructed barley-hummeller, manufactured by Messrs Ransome and Sims, Ipswich. The machine stands about 4 feet high: *a* is the handle by which it is worked, *b* the hopper, *c* the delivery-spout, *d* the bolts to fix it to the floor. Fig. 491 is a vertical section, and fig. 492 a sectional plan showing working parts. A spindle *a a*, 1 inch diameter, revolves vertically in the step *b*, and in the bearing of the curved

Fig. 490.



RANSOME AND SIMS' BARLEY-HUMMELLER IN PERSPECTIVE

Fig. 491.



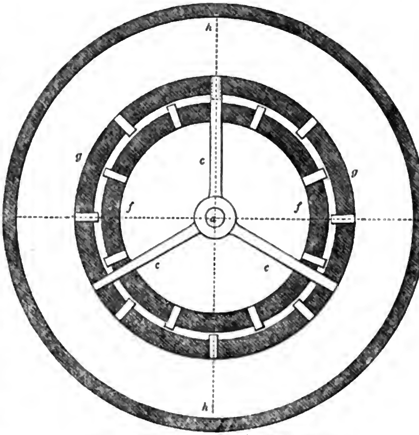
VERTICAL SECTION OF HUMMELLER—SCALE, 1½ INCH TO THE FOOT.

guard *c c*, connected at its extremities to the sides of the machine. Motion is given to this shaft by the bevel-wheel *d d*, shown by dotted lines, keyed on to the spindle of the handle *a*, fig. 490. This bevel-wheel *d*, fig. 491, engages with another, *e*, half the diameter, keyed on to the vertical shaft *a a*, a little above the bottom step *b*. To the central shaft *a a*, a cylinder *f f*, 13 inches in diameter and 5½ inches high, is connected. This carries on its periphery a series of wrought-iron pins. These pass between the spaces formed by pins placed in the interior periphery of the outer cylinder *g g*, the diameter of which is 16 inches, and height 6¼ inches. The barley is put into the hopper *h h*, the diameter of which, at top, is 1 foot 10½ inches, and height 9 inches.

1349. *Rankin's Corn-Cleaner and Smut-Machine.*—We now present illustrations of a double-action smut-machine and corn-screen, as manufactured by Messrs R. & J. Rankin, Manchester Street, Liverpool. Fig. 493 is a side elevation of the machine, drawn to a scale of ½ inch to the foot. The corn to be cleaned is delivered by the spout *a* to the elevator *b b*, the buckets of which, *c c*, deliver it to the separator *e* by the spout *d*. The refuse, as nails, stones, &c., pass from the spout *f*, while the grain passes down the spout *g* and *h*, to the cleaner. This is formed of a cylinder, the upper part of which is made of fluted iron, the lower part of wire-cloth. In the interior of this cylinder another cylinder revolves, provided with beaters. The beaters, acting on the wheat, in conjunction with the fluted iron and wire-cloth of the cylinder, cleanse the wheat from all smut, and force it through the sides to the space between the cylinder and the outside casing *i i*, which space acts as a dust-box. Powerful fanners are placed at the top of the casing at *i i*, and drive off all smut, chaff, &c., which are finally passed from the machine by a side spout. The cleaned grain is then delivered by the spouts *k k*, the refuse passing from the space between the outside and inside casing by the spout *l*. The whole is supported by the pillars *m m*. Part of the cylinder *i i* is shown in section; its upper part, with the fluted bars, is shown at *n n*; the lower part, of wire, at *p p*; the interior revolving cylinder, *o o*, has longitudinal beaters.

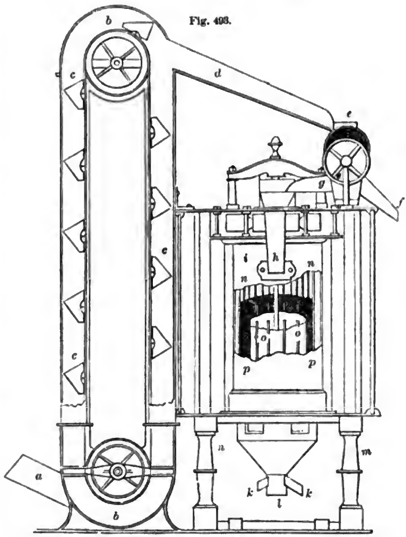
1350. There has not yet been sufficient experience of the English thrashing-machine in Scotland to form a correct judgment of its su-

Fig. 492.



PLAN OF HUMMELLER—SCALE, 1½ INCH TO THE FOOT.

Fig. 493.



RANKIN'S CORN-CLEANER AND SMUT-MACHINE—SCALE ¼ INCH TO THE FOOT.

periority over the Scotch thrashing-machine. Scottish farmers, however, seem already convinced that the beater or drum of the English machine takes the grain more cleanly from the straw, breaks the straw much less, and thrashes out a larger quantity of grain in a given time than the Scotch machine. Thus far the English machine affords decided advantages. On the other hand, it has been found that the English machine indents or mutilates the grain itself, especially new or unwon wheat, and even destroys its vitality. It is believed that if the downy substance at one end of the grain of wheat is taken away, the grain loses its vitality. It is quite possible that the sharp quick stroke of the English beater may actually injure the grains of wheat, and so may those beaters which rub out the corn from the straw, but one can hardly suppose that either the beating or the rubbing of the English drum could remove the downy substance from the grain; so that if the vitality of wheat is really affected by the English machine, it must be so by the hummeller within it, which seems to us to endeavour to do too much in the way of cleaning the grain by a thrashing-machine. It is well, indeed requisite, that a thrashing-machine should take the grain from the straw, and divide the grosser impurities of chaff and roughs from the grain, but a question may reasonably be raised whether the grain should be cleaned to the degree fit for market by the thrashing-machine. For our part, we have never yet seen a thrashing-machine that cleaned the grain as it should be for market, according to our judgment of cleanliness; and, in our opinion, the English machines attempt too much, and run the risk of injuring the grain. Now, the Scotch machine, by its slow motion, never injures the grain, and few attempt to clean it for the market; but the cleansing process by the Scotch fanners and the hands of women-workers is perfect and innocuous. The improvement which we would therefore desiderate in Scotland in the thrashing of grain, is the adoption of the high-speed English beater to the degree of not injuring the grain, with a combination of the most perfect Scotch cleansing process. Under such auspices the grain would escape injury, and be perfectly cleansed to the degree to insure its vitality. It is the true object of the farmer to preserve the vitality of the grain he sells, that it may be sold alike to the farmer to be sown, or to the miller to be ground. If the miller finds that the farmer's extent of cleansing does not suit him, he must himself prepare the grain for his own purpose; but the farmer, for his own interest, must on no account adopt any process that will deprive the grain he has to sell of its vitality.

1351. We may here mention that the shakers adopted in the English machines —namely, those with the reciprocating and saltatory action—are of Scotch origin. The invention of the principle was claimed by two persons simultaneously—Mr Docker, Findon, and Mr Ritchie, Mill of Melrose, both in Banffshire; and both inventions are described and figured in the 12th vol., p. 195, of the *Transactions of the Highland and Agricultural Society* for 1837; but the claim made by Mr Docker seems to have been as early as the 4th of April 1829.

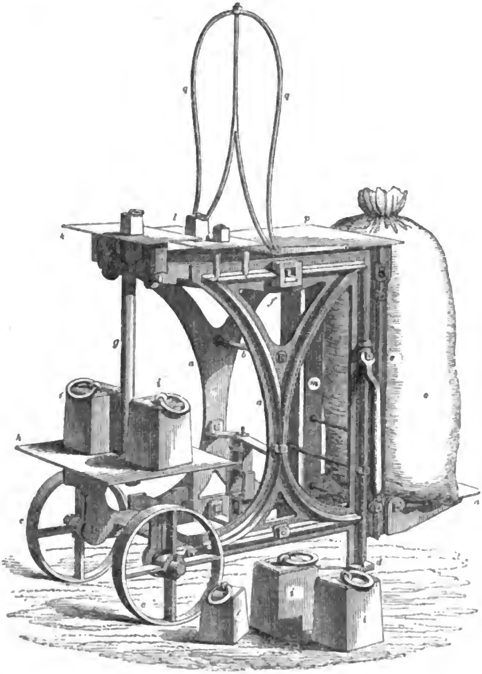
1352. *The Barn Weighing-Machines.*—The weighing-machine is an important article of the barn furniture, and various forms of it are resorted to.

1353. The common beam and scales is the most correct of all the instruments of the class; but it is defective, as being less convenient for the purposes of the barn than several others that are partially employed.

1354. Steelyards of various forms are also used; but in all steelyards there are grounds for doubting their accuracy, in consequence of the operator not seeing the true counterpoise of the substance weighed, but only its representative, bearing an actual weight greatly smaller than the substance, but in the inverse proportion to it that the longer arm of the steelyard on which it is appended bears to the shorter arm. Many of these steelyards, from their compactness, are, however, greatly to be commended; and, when well constructed, and properly adjusted, will be found to answer the purpose of weighing such bulky articles as grain with sufficient accuracy. Their cheapness also, when compared with some other instruments on the beam-and-scale principle, holds out a great inducement for their adoption.

1355. *The Balance Weighing-Machine.*—A weighing-machine, on the balance principle, which combines every convenience for the setting on and removal of the bags of grain with accuracy and neatness of construction, is exhibited in fig. 494. This machine is constructed chiefly of cast-iron; the framework *a a* is connected by cross-stretcher bolts *b*, and is supported in front on the wheels *c c*, while the back parts are supported on the feet *d*. The folding

Fig. 494.



THE BARN BALANCE WEIGHING-MACHINE.

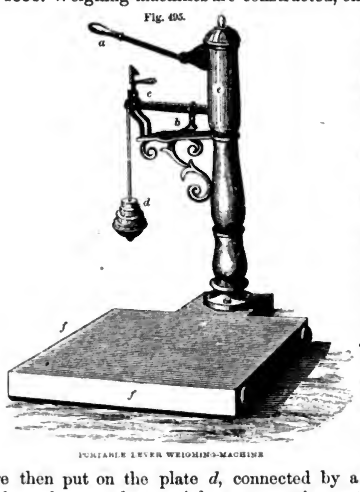
handles *e*, one on each side, turn on a joint pin at *e*, and become levers by which the machine can be moved about like a wheelbarrow. The beam, parts of which are seen at *f f*, is double, and also formed of cast-iron, with steel centres, the two bars forming the beam-stand, and are connected by a diagonal truss. The one end of the double beam supports a cross-head suspended on the end centres of the beam, and to which is attached the pillar *g*, to the lower end of which is attached the shelf-plate or scale *h*, upon which the principal weights *i i* are placed. The cross-head carries also the top shelf or scale *k*, upon which the smaller weights are placed, and a dead plate *l* is fixed on the framework on which the small weights stand ready for use. The opposite ends of the beam carry a frame *m*, only partially seen, to the lower end of which the shelf *n* is jointed, and upon this shelf the bag *o*, about to be weighed, is shown in the figure. To the upper end of the frame *m* there is also attached, by a strong bracket not seen in the figure, the shelf or scale *p*, and upon this scale the bag may be placed and weighed with equal accuracy, while it is supported by the light frame *q q*. The object of the top and bottom weighing-shelves is to suit the placement, or the removal of the bag, either from or to a man's back by the top shelf, or from or to the corn-barrow by the lower shelf. When the machine is not in use, the lower shelf *n* is folded up against the back of the frame, and the light frame or back *q q* folds down by a jointed arm over the folded-up lower shelf *n*, reducing the machine to a very compact state.

1356. In weighing with this machine, from its being on the principle of the balance, the amount of weights required is equal to the absolute weight of the body that is being weighed, and the true weight is determined when the scales or shelves *k* and *p* coincide in one level line with the dead-plate *l*.

1357. In constructing this machine, the bottom of the pillar *g*, and of the frame *m*, are provided with a horizontal connecting-rod, which preserves their parallelism, and, consequently, the correct indications of the beam.

1358. Weighing-machines are constructed, on the same principle, with wooden framework, which renders them lighter and cheaper; but from the changeable nature of the material, as affected by moisture and dryness, they are liable to derangement.

Fig. 495.



PORTABLE LEVER WEIGHING-MACHINE.

1359. The price of this balance weighing-machine is £8, 10s.; and when constructed in wood the price is £5 or £6.

1360. *Portable Lever Weighing-Machine.*—In fig. 495 we illustrate a portable lever weighing-machine, in which small weights on the lever *c* balance heavy weights on the platform *f f*. When the lever *a* of the standard *e* is up, as in the diagram, any weight placed on *f* does not affect the balance-beam *c*; but on pulling it down, it puts the platform *f* in connection with the beam. Weights are then put on the plate *d*, connected by a rod with the extremity of the balance-beam *c*, these weights representing cwts. The beam *c* is divided into parts, each showing a pound, from 1 to 56 lb. After bringing the beam *c* nearly to the balance-level, the sliding-weight *b* is moved along it till the balance is accurately obtained. The weight at *d* shows the number of cwts., and the weight *b* indicates on the scale of the beam *c* the number of pounds beyond the cwts. the article placed on the platform *f f* weighs.

1361. As manufactured by Messrs Dray and Co., the price of a machine of this class, to weigh 5 cwt., is £5, 15s.; to weigh 10 cwt., £8, 16s.; and to weigh a ton, £13.

1362. The same firm manufacture a modification of this weighing-machine, adapted to weigh calves. This is provided with a movable pen, which is placed upon the platform *f f*, fig. 495, and in which the calf to be weighed, is placed.

1363. Section Fourth.—*Carts, Waggons.*—In Book First, Fourth Division, Second Section, from pages 124 to 138, we have gone into the consideration of the philosophy or theory of the action of wheel carriages; it now remains for us to describe the construction of their component parts, and to point out some things of the principles which direct the modern wheel-maker.

1364. *The Construction of Wheels and Axles.*—With but few exceptions, carriage-wheels of all sorts are constructed principally of wood, but bound and supported with iron; such a wheel for one-horse carts consists of the *nave*, a turned block of wood, usually elm, 12 inches long, and from 10 to 12 inches diameter, bound at each end with iron hoops: it is pierced with twelve mortises equally divided around it, into which are firmly inserted a like number of *spokes*, always made of oak. A ring of wood in six segments or *felloes* is mortised upon the extremities of the spokes, and this is surrounded by the *hoop* or *tire* of iron, either in one unbroken ring, or in segments.

1365. Of wheels so formed there are several varieties. That *without the dished* character may be held as a nonentity, except in carriages of one wheel or of three wheels, where the third or front wheel may be found without dish, and in some cases where a double inverted dishing is adopted. The *dished* wheel is that which has its spokes so placed in the nave that, if laid with the end of the nave upon an extended flat surface, the point of each spoke would be farther distant from that surface than the root where the spoke enters the nave, and the spokes of the wheel thus arranged, when put in revolution, would describe a cup or dish-form figure, concave above, forming the front of the wheel, and convex below, forming the back.

1366. The class of dished wheels are separated again into two great divisions —the *conical* dished wheel and the *cylindrical*. The conical is known chiefly in England, and is that in which the tire, properly so called, is applied in segments; and sometimes, as in the wheels of very large waggons, the tire is composed of two, three, or four breadths of iron. In wheels of this kind the tire is sometimes applied in one ring or hoop; but its object as a binding-hoop is in a great measure frustrated by the conical surface to which it is applied, and hence the necessity of such solid tires being secured by strong rivet-bolts passing through it and the felloes, to prevent its dropping off the wheel. The cylindrical wheel, like the conical, may have any degree of dishing given to the spokes; but the sole of the felloes or periphery is worked off at right angles to the plane of the felloes, and consequently cylindrical wheels of this kind are always hooped with an entire ring of iron, applied when red-hot; its contraction, therefore, when cooled, brings the felloes into close contact with themselves and the iron, and affords the greatest possible strength to the wheels.

1367. The sole or tire of conical wheels varies in breadth from 4½ inches to

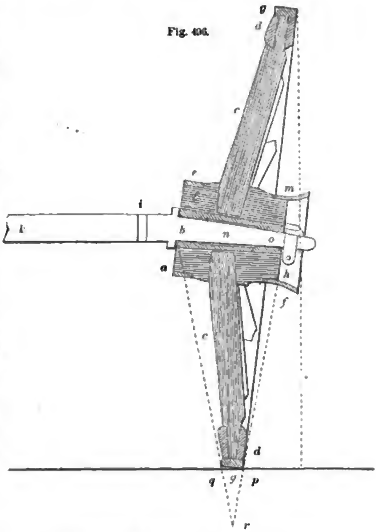
16 inches, the latter being found only in the largest class of carrier's waggons, while the former, and intermediate sizes, are to be seen on two-wheel carts and all intermediate carrying vehicles. The sole of the cylindrical wheel is seldom above 6 inches, generally 5 inches; but the great bulk of them is $2\frac{1}{2}$ to 3 inches broad. Wheels of this form, when above 3 inches broad in the sole, are run upon straight axles, the plane of the felloes being vertical, hence they move without any tendency to deviate from a straight line. Those with a sole of 3 inches and downward, usually run upon bent axles, as afterwards more particularly described, and hence partake a little of the tendency of the conical wheel, the plane of the felloes standing oblique to the vertical.

1368. A great deal of irrelevant matter has, from time to time, been put forth on the subject of dished and conical wheels, in some cases deviating so far from the subject as to mistake the one quality for the other, and exhibiting such a want of information on the English practice of using conical wheels, as to represent a highly dished and conical wheel running in a waggon, with the plane of its felloes standing vertical—evidently intended to exhibit their destructive effects on the roads, by cutting them up in a way that never occurred except in the mistaken imagination of the writers. Similar incongruities are to be found respecting the dishing and form of the wheel, where the conical character is confounded with that of dishing, probably arising from the absence of a true conception of the terms as applied in practice. It is pleasant, however, to see that men of talent are still found, who will devote their energies to the elucidation even of this everyday subject, and that with a degree of simplicity and perspicuity not hitherto to be met with on this subject. Thus, in the volume of *The Library of Useful Knowledge* chiefly devoted to the "Horse," there is a treatise on Draught, in which the principles and the defects of *conical* wheels are so clearly illustrated, that nothing remains to be said in condemnation of the practice. Instead, therefore, of spending time in attempting to elucidate their construction and defects, it seems better to allow them to take their place among the things that *have been.*

1369. *Of the Wheel.*—To proceed, then, in the consideration of the *cylindrical wheel*, and, in connection with it, to consider also the formation of the axle, it must be observed that there are two varieties, the inclined and the upright, though both varieties are *dished* wheels; and of these the first to be considered, as being the oldest, is the inclined cylindrical wheel, as it is seen in section in fig. 496. In this figure *a e* is the nave, with the axle *b* passing through it. The spokes *c c* are represented as they are inserted in the nave, and as they pass through the felloes *d d*, and these are encircled by the iron-hoop or tire, seen in section at *g* and *g*, which, when complete, serves to bind and compress the entire ring of felloes into one mass. This common cart-wheel is seldom made below 54 inches in diameter, nor exceeding 58 inches, measuring over the iron hoop. The ordinary length of nave is 12 inches, and its diameter varies from 10 to 12 inches. In an average diameter of 11 inches in the middle, the inner end of the nave is 10 inches, and the outer end 9 inches; at the inner end, it is bound by an iron hoop *a e* of 2 inches in breadth by $\frac{3}{8}$ inch in thickness, and on the outer end by a hoop *f m* of 4 inches in breadth, about one-half of which projects beyond the end of the nave, forming a shield to defend the end of the axle from accident and from mud. The iron for the outer hoop or band is manufactured for the special purpose, the edge of the bar intended for the outward part being $\frac{3}{8}$ inch in thickness, while the inward edge is not more than $\frac{3}{16}$ inch.

1370. When a block has been selected for the *nave*, an auger-hole is bored through its axis; into this an iron bar or mandrel is driven, and upon it the nave is turned to the proper shape and dimensions, and lines drawn round it limiting the length of the intended mortises. Its circumference is then divided into twelve equal divisions, and upon these divisions, as a centre, an auger-hole is bored upon each in the direction of the radii of the circle—or if machinery is applied in the manufacture, the nave is suspended between proper centres, furnished with a dividing index, and the vertical drilling-machine brought to bear upon the nave, dividing and boring it at one operation. The enlargement of the hole is then performed either with the mortising-chisel and hand-mallet, or by the mortising-machine, until the mortise is of the proper size and direction. In forming the mortise, its *sides* ought to be parallel, the width from 1 inch to $1\frac{1}{4}$ inch; the front end must be cut to the slope of the intended *dish* of the wheel, while the back of the mortise approaches nearly to a right angle with the axis of the nave.

Fig. 496.

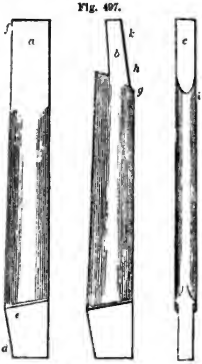


SECTION OF THE INCLINED CYLINDRICAL CART-WHEEL.

1371. A practice has been long prevalent to make the mortises wider at the front than at the back; and in support of the practice it has been alleged that it tends to keep the spoke firm in its mortise, and at the proper inclination. Little consideration is necessary to show that the practice can neither accomplish the one nor the other, but it involves a condition much worse than this negative quality, which is, that it leaves less substance of wood in the bridge or partition between the mortises at the front than at the back, thus inducing an unnecessary weakness in that part of the nave more than at the back, and though this may not exceed $\frac{1}{8}$ or $\frac{1}{4}$ of an inch in each partition at the surface, it forms a more sensible proportion of it towards the bottom; and as the nave is the basis on which the whole wheel depends, every means ought to be adopted to secure its uniform strength.

1372. The *spokes* of the wheel ought to be prepared of the best oak-root, thoroughly seasoned, for which purpose they require at least three years' preparation. The length of the rough spoke is 27 inches, and when dressed to enter the nave, the breadth at the root is from $3\frac{1}{4}$ to $3\frac{3}{4}$ inches, the thickness of the body ranging from $1\frac{1}{4}$ to $1\frac{3}{4}$ inch. Fig. 497, *a* is a side view of a spoke when prepared to be driven into the nave, *b* the same when it has been finished in the wheel, and *c* a front view of the same in the finished state. In figure *a*, the form of the root tenon is exhibited, wherein the front edge is uniformly straight, but on the back the tenon part is wedge-formed, the slope *d e* deviating from the line *e f* a quantity nearly equal to the dish which the spoke is intended to have in the wheel, whereby the back of the mortise approaches to a right angle to the axis of the nave. In wheels where the dishing is carried to an excess, this rule would give the tenon so much of the wedge-shape as to render it very liable to be dislodged from the nave; and hence, as one evil begets another, arises the necessity for giving the back of the mortise an inclination, or what is termed being ***under-cut***, which induces the further necessity of weakening the partition behind by sloping the back of the mortise, or the alternative of giving it less width behind than in front; but every one of these conditions should be avoided as much as possible. The shoulders of the tenon, instead of being cut in at right angles to the faces of the tenon, are usually cut at an angle of not less than 45°, as seen at the figure *c*; these, when the spoke is driven home, fill up firmly the parts which are cut away for this purpose in the two edges of the mortise, giving to the spoke a more stable bearing on the shoulders, and, at the same time, increasing the strength of the tenon at this essential point. Figure *b* is exhibited finished at the head, though this operation is performed only after it has been driven into the nave. The face-edge *k h* of the head tenon has its plane dependent upon the amount of dish, for the part from *k* to *h* is always cut off at right angles to the axis of the wheel, being also parallel to the intended face of the felloes. From the point *h* towards the body of the spoke, the face is usually curved to *g*, as in the figure, the principal use of which is to facilitate the formation of the curve given in the finish of the face of the spoke, as seen at *i* in figure *c*. The back part of the head tenon is quite arbitrary, but it is proper to give it greater breadth at the root than at the point by about $\frac{1}{4}$ inch.

Fig. 497.



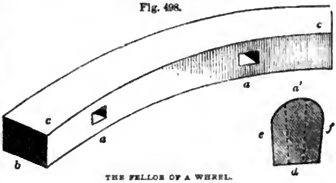
THE SPOKES OF A WHEEL

1373. The fitting of the mortises of the naves to the spokes is an operation requiring considerable care; the front of the spoke must be set at the proper angle of dishing, which should not be under $82\frac{1}{2}$° with the axis of the wheel, nor should it exceed 84°, or nearly $1\frac{1}{4}$ inch, and 1 inch on each foot of the length of the spoke. It is difficult, and unnecessary, to determine the degree of force requisite to drive the spoke into the nave, but it may be affirmed that there may be as much injustice done to the fabric by having the spokes too firmly driven into their mortises, as by having them too easy: the danger of the former arises from overstraining and crippling the partitions of the nave; and of the latter, from the spokes becoming loose in the mortises;—a due mean between these, which can only be judged of from experience, will always produce the most lasting results.

1374. It is deserving of remark, that, for some reason now lost in the obscurity of time, the tenon at the point of the spoke is almost invariably formed with a shoulder or bearing on one side only, as in fig. 497, *b*. From the manner which the pressure comes upon the felloe and the spoke being that of compression on the end of the spoke, it would certainly appear more natural that it should be ***shouldered on both sides***, but more especially in the wheel with broad felloes. Here, I should say, it is indispensably necessary to the due stability and support of the wheel; nevertheless it is seldom, if ever, adopted, except in the practice of a few wheel-makers.

1375. The *felloes*, in a wheel of ordinary size, are always six in number, and are usually either of ash or elm; they ought also to be well seasoned, and of sound quality; the breadth, from front to back, is from 3 to $3\frac{1}{2}$ inches, and their depth $3\frac{1}{2}$ to 4 inches. Fig. 498 is a view of a felloe square-dressed and mortised, being in the state in which they are first prepared previous to being put on the spokes; *a a* are the mortises, and *b* is the dowel-hole, as bored in each end of the felloes.

Fig. 498.



THE FELLOE OF A WHEEL.

1376. The *dowels* of wheels are usually of oak, $\frac{3}{4}$-inch diameter, barrel-shaped, and their chief use is to keep the joinings of the felloes fair and even while finishing, and until the tire is put on.

1377. The felloes, previous to their being put on the spokes, are partly rounded off to the form seen in section, fig. 498, *a′*, in which the dotted lines represent the mortise, *f* the face, *e* the back, and *d* the sole, of the felloe. After being put on the spokes, dowelled and wedged up, the felloes are dressed thoroughly off either by turning, or by the plane and other hand-tools, the periphery, or sole of the wheel, being dressed off *square* to the face of the felloes without being at all conical. In fitting the end-joinings of the felloes, which is done by running a saw several times through the meetings, and in finishing the joints, it is proper to leave them open outwardly, or towards the circumference, because, from the felloes being generally cut out of straight wood, the parts *c c*, of two contiguous felloes, when presented to each other, have the grain of the wood abutting obliquely, and hence liable to compression when brought to their bearings: this occurs when the tire or hoop is applied; and to admit of the full effect of the hoop as a binder, the end joinings of the felloes are all finished slightly open.

1378. The application of the *tire* or *hoop* is the next process in the construction of the wheel. For narrow wheels, which are now under description, the iron of the hoop is from $2\frac{1}{2}$ to 3 inches broad—seldom 3 inches—and the thickness from $\frac{3}{4}$ inch to 1 inch. The bars are first bent in the cold state to the curve, either by passing them through a three-roll machine, or, what is simpler, they are bent over a curved block of somewhat smaller diameter than the intended wheel. When brought to the circle the ends are welded, but, previous to doing so, the length of the circumference of the wheel, and the length of the inside of the hoop, are compared. This operation is performed by measuring the length of the circumference by means of a simple *odometer*, a small iron wheel turning upon a pivot, which is held in the hand; with this the length of the external surface of the felloes is measured, and also the internal surface of the hoop, and when welded up, the internal surface of the hoop should be 1 to $1\frac{1}{2}$ inch shorter than the external surface of the felloes, proportioned to the allowance that has been given for the closing of the felloe-joints. The hoop having been set tolerably correct to the circle, and also out of twist, it is heated either in the forge fire, or in a pile; but what forms the most perfect and economical mode of heating is the hoop-furnace, in which, as well as in the pile, two, four, or more hoops may be heated at once. In this operation the heat required is only such as will produce that degree of expansion in the fire which will make it pass freely over the wheel, and for this purpose a dull red heat is sufficient. The wheel is laid on a hooping bed of stone, or of cast-iron, with its front downward; the heated hoop is brought over it; if sufficiently expanded and true to the circle, it passes on to the wheel with little trouble, and at most with a few twitches of the hooked lever, or a blow of the hammer, it takes its place. Cold water in abundance is immediately applied to the iron, serving at the same time to prevent the burning of the felloes and to expedite the contraction and tightening of the hoop: so soon as it begins to bite, the wheel is turned up, and the wood and the iron are adjusted to each other. The iron is now cooled down to prevent all deterioration of the wood, the wheel being thus strongly compressed on all points, the shoulders of the spokes against the felloes, and the joinings of the latter brought also into close contact. This operation, by compressing the joinings of the felloes, while they are resisted by the spokes from contraction of the wheel's diameter directly, has always the effect of increasing the dishing of the wheel, by the spokes yielding forward in obedience to the contraction of the iron, and the compression of the felloes. It is necessary, therefore, in the first construction of the wheel, to make allowance for this; and to this end $2\frac{1}{2}$ inches of dish will be sufficient before the iron is applied, as it will then be increased to nearly 3 inches. In wheels hooped in this manner, the only fixing given to the hoop beyond that of contact is a spike driven through it into each felloe, and the only use of the spikes is to prevent the hoop falling off in the case of the felloes shrinking in a long course of dry weather.

1379. The *bushing* of the wheel is the concluding process. The bushes are of various sizes, suited to all purposes; for wheels such as we are here describing, they are $2\frac{1}{2}$ inches and $1\frac{1}{2}$ inch diameter, or $2\frac{3}{4}$ inches and $1\frac{3}{4}$ inch—the cart-wheel bushes in common use being always tapered in these proportions. They are cast with a *chilled* interior surface, that is, cast upon a turned iron core or mandrel, which gives them a tolerably smooth surface, with considerable hardness. In setting the bushes in the wheel, they must be placed so as to have their axis in the centre, and at right angles to the face of the wheel; and to insure the attainment of these points, the wheel, with the bush fitted in, should be suspended on the axle, and the bush adjusted with wedges, so as to make the wheel revolve truly.

1380. The foregoing description has reference to narrow wheels; but in the case of the common Scotch broad wheel, the only point of difference lies in the greater breadth of the felloes and the hoop. The dishing is usually the same as for the narrow, though, according to the ordinary views of the case, the dishing ought to be less, or to vanish entirely. This, however, would weaken the wheel much more than any ordinary amount of dishing could produce; and this for reasons that will immediately be shown. In the broad wheel the felloes have the same depth, or nearly so, as stated in par. 1374; but the breadth varies from 4 to 6 inches. The spokes are usually finished in the same manner as in fig. 497; but the mortises of the felloes are placed farther from the face, so as to throw the bearing on the spoke, nearly in the middle of the breadth. The hoops are, of course, suited to the breadth of felloes, but the thickness is always less than in those of narrow wheels—seldom exceeding $\frac{3}{4}$ inch, and descending to $\frac{1}{2}$ inch.

1381. *Of the Axle.*—Cart-axles are always prepared in the form of blocks under the forge-hammer, and are afterwards finished to the true form on the anvil, with the hand and sledge-hammer. Fig. 499 is a view of an ordinary

Fig. 499.

THE CART-AXLE.

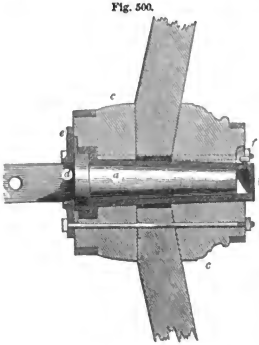
cart-axle in the finished state, and adapted to narrow wheels. The body part, from *a* to *b*, is $1\frac{1}{2}$ inch thick, and $2\frac{1}{2}$ to $2\frac{3}{4}$ inches in depth; it is thickened at *c* and *d* to a breadth equal to the diameter of the arm, for the purpose of admitting the opening of the caddy bolt-holes *c* and *d*; the arms of this example being $2\frac{3}{4}$ inches diameter at the shoulders *e e*, and diminishing to $1\frac{3}{4}$ inch at the linch-pin holes *f f*. In preparing the axle on the anvil, an incision is made along the lower side of the arm in the parts which will bear upon the bushes, and a strip of steel is laid thereon and welded into and upon the arm. When finished and hardened, this presents a smooth and durable surface on those parts of the axle where the greatest pressure occurs, thereby at once lessening the friction, and increasing the durability of the axle.

1382. In axles of the common construction, the arms are simply rounded and dressed a little with the file till they enter freely into the bushes. In connection with this rude finish, an opinion prevails among workmen, that a transverse section of the arms should not be a circle, but an oval, or approaching to the figure of the longitudinal section of an egg, the lower side on which the pressure exists corresponding to the end of the egg. This form, it is alleged, by allowing the bush to touch the axle on a line passing along its lower side, and again on the fore-part towards the upper side, produces less friction than if the surface of the arm were a perfect cylinder, or rather cone; and having also the advantage of a space before and behind the line of bearing in which the grease has a lodgment, and ready at all times to lubricate the bearing part of the surface. It must be admitted that there is some show of truth in the latter part of the allegation, but the former is assuredly one of the vulgar errors; for if it is true, as shown by experimenters, that with the same load friction is not increased by an extension of the rubbing surfaces, then there can be no extinguishing of friction from a decrease of the bearing surface on the axle; and even to admit, according to some experimenters, that there is a slight increase of friction by an extension of surface, it would form such a small amount, the whole being but $\frac{1}{20}$ of the draught, that any reduction of that friction cannot possibly be otherwise than of very little importance.

1383. The more refined mode of finishing the axle-arms by turning is unquestionably the best adapted to destroy friction, especially when the surface of the bush has been also bored, or otherwise rendered accurately round and smooth. The retention of the grease is also partially accomplished by the chamber formed in the central part of the bush, seen at *n*, fig. 496. But the best proof of the advantages of turned and well-fitted axles is derived from the performance of the royal mail and stage coaches, whose axles fit their bushes so exactly as to be almost air-tight. In these, it is true, the constant lubrication is effected in a very perfect manner by the bush being converted into an air-tight chamber, which retains the grease without risk of its being squirted out. The want of some more secure means of retaining the grease in the cart-axle is a serious inconvenience and loss; for if the grease is so *thin* as to be completely useful, it is squirted out of the open bush in a very short time, causing a loss of the material; to obviate which, it is compounded in such a manner as to give it a consistency that will prevent its too free discharge; but by the same means it is rendered less serviceable as a lubricator, and a consequent small increase of friction ensues from that circumstance.

1384. There are two kinds of such axles and bushes especially in use. That known by the name of the Mail-coach patent axle retains the principles of the tapering and bent axle, and is exceedingly simple and effective, though not quite so elegant as that known as Collinge's patent, used for light carriages; but the mail axle is best adapted for such vehicles as carts. A section of the *mail-coach* *axle and bush* is here exhibited in fig. 500, wherein *a* is the arm of the axle, and *b* the bush, *c c* being the nave in which it is enclosed. The bush is cast on a turned mandrel, and thereby hardened; a chamber is formed in the mouth of it, to which the axle is accurately fitted, the collar *d* filling exactly the chamber at the mouth. The outer end of the bush is solid, and it is rendered grease-tight at the mouth by means of a leathern packing or washer applied to the end of the nave and embracing the axle; this is again covered by the iron-plate or collar *e*, which, besides retaining the solid collar of the axle in the chamber of the bush, is brought home to the end of the nave and bush by three bolts, which, passing through the plate and the nave, are tightened at the outer end of the latter by screw-nuts, until the collar of the arm has just freedom to turn in its chamber. The reservoir for the grease is the open space between the point of the axle-arms and the bottom of the bush, and the charge of grease is introduced to this chamber through a small opening at *b*, which is closed by a screwed plug *f*.

Fig. 500.



THE MAIL-COACH AXLE.

1385. Axles of this construction require a peculiar mixture of grease, which shall have such a consistency as to prevent its escaping too freely by the side of the collar *d*; hence any pure oil is not suitable for the purpose, because of its too great fluidity causing it to be speedily exhausted. A composition that is well adapted to these axles consists of equal parts by weight of whale-oil and lard, with about $\frac{1}{8}$ part of vegetable tar. The mixture, when cold, is of a consistency similar to honey, requiring to be heated to render it so fluid as to pour into the orifice of the bush, where it is again congealed, until by the motion of the wheel a sufficient temperature is produced to keep the grease in a state capable of lubricating the surfaces without becoming so fluid as to escape by the collar.

1386. A variety of axles have recently been introduced, but are too elaborate to be recommended for the purposes we have here in view; we therefore deem it unnecessary to go into details respecting them.

1387. Of the inclination of the axle-arms much has been said and written, and demonstrations innumerable produced, to show that axles should have certain forms that are, in fact, impracticable, and others that never can, or never have existed, except in the diagram of the mathematician. Certain points in the subject have apparently been taken up originally under theoretical, and even mistaken views, and the conclusions drawn from these have been, of course, participations in the original error; but what is more unfortunate, they have been received and handed from one to another with all their faults, the subject, as it would appear, being considered by succeeding writers not worthy of the trouble of being again taken up at the fountain-head of experiment, or of resorting to the induction that may be derived from everyday experience. Without entering, therefore, into, or following any of those learned discussions, we shall take a simple practical view of the case, referring, when necessary, to previous conceptions of the subject.

1388. It has been held by some writers who have treated this subject, that the position of the *axle-arm* should be such as to have its lower or bearing side at right angles to the position of the spokes that are at the moment bearing the load of the axle, the bearing-spokes being, by hypothesis, at the time vertical; it being supposed, under this view, that the dishing of the wheel is adapted to bring out this result, and that any deviation from this rule will produce an undue pressure of the end of the nave and bush against the collar of the axle, if the arm droop at the point, or against the linch-pin, if the arm is turned up from the horizontal line at the point. It will be observed that this proposition implies that the lower or bearing side of the axle should always be horizontal, and this without reference to the degree of taper given to the arm. Now, such a proposition might possibly have applied at a time when wooden axles were almost exclusively employed, the taper of these having been much greater than is required for those of iron. But were it essential that the lower spokes should stand perpendicular, and the principle be carried out to the iron axles now in use, whose taper amounts to 1 inch on 12 inches, or ½ inch on each side, it would follow that the dishing of the spokes would amount to only ½ inch on the foot, or about 1¼ inch of entire dish; and, from what has been said in the latter part of par. 1378, this is too little to afford sufficient support and strength to the wheel. In practice, we find that all the above conditions may be deviated from with impunity; for with dished wheels, and the arms of the axles bent downward, the most perfect freedom of action is found to exist: and not only in this case, but with broad-dished wheels running upon straight axles with arms tapering in the same degree as the former, a like freedom of action is obtained. It appears, therefore, that the points hitherto considered by writers on this subject as of essential importance in the formation of the axle, and the relative position of the wheel, may be departed from without inconvenience, and that the requisite freedom of action of the wheel upon the axle-arm is to be accounted for from other causes than have hitherto been recognised.

1389. Having pointed out what appears to us as fallacies existing in the hitherto received opinions as to the proper form of the axle, we have now to add, on this part of the subject, a few remarks on the common practice method of making the cart-axle in Scotland, chiefly as regards the *setting* or form of the axle.

1390. The practice has long prevailed of bringing the wheels of vehicles intended for load to one standard of width, where they touch the surface of the ground; and this standard or gauge has, by long-established use, been fixed at 4 feet 4 inches between the tread of the wheels, where they rest on the ground; and as the breadth of the hoop in narrow wheels is 2½ inches, the gauge over all is 4 feet 9 inches. By a corresponding usage, the length of the axle-bed, or that part of it lying between the collars *e* and *e*, fig. 499, has been fixed at 3 feet 6 inches, thus affording two fixed conditions in the problem.

1391. Were all wheels made with one uniform degree of dish, we should then have one simple standard for the *set* of the axle-arms, which would be this: Let the concavity, or true dish, in the front of the wheel, and measured at the surface of the nave by 2½ inches, the entire deflection from the base of the nave *a e*, fig. 496, to the front of the felloes, will then be 10 inches, and were the axle straight, the wheels would stand at the distance of 3 feet 6 inches, + 10 inches + 10 inches, or 5 feet 2 inches over all; but as they must be brought to the gauge of 4 feet 9 inches below, each wheel will be brought to an inclination of 5 inches from the perpendicular upon its entire height, or it is 1.12 inch nearly on each foot of its height.

1392. It is evident that, since the axis of the axle-arm must stand at right angles to the face of the wheel, whatever degree of inclination the wheel makes with the vertical line, the axis of the axle-arm must make an equal degree of inclination with the horizontal line, or its deflection will be also 1.12 inch upon a foot of its length. The axis, or central line, of the arm will therefore *hang*, or be bent downward at the point 1.12 inch below the straight line, passing along the central line of the body of the axle; but as it is easier in practice to operate upon the lower side of the axle-arm than upon its axis, deduct half the difference of the diameter of the two ends of the arm, which, in ordinary cases, is $\frac{1}{2}$ inch, and this deducted from the deflection due to the axis or central line, we have .62 inch, or $\frac{5}{8}$ nearly, remaining for the deflection of the lower side of the arm. This quantity is, however, subject to variation from two causes—the dish of the wheel, and the diameters of the axle-arm; but the rule will apply to all cases; and though it does not produce a perfectly correct form of the axle, being defective in principle, yet it approaches so near the truth that we are surprised to find such a close approximation produced simply from experience, for it does not appear that the *principle* has ever been detected on which the practice has probably, by accident, been based. In most of the attempts made to establish a principle on which the form of the axle ought to depend, the demonstrations have failed by a misconception of the direction in which gravity acts through the medium of carriage-wheels.

1393. The rule above referred to may be stated more concisely thus: *To the length of the axle-bed add twice the deflection of the wheel, measured from the base of the nave to the face of the felloes; from this sum subtract the intended over-all width of the wheels at the ground, and the remainder will be the deviation of the face of the wheel from the perpendicular. Divide the last acquired number by the diameter of the wheel for the deviation per foot, which will also apply to the central deflection of the axle-arm, and subtracting half the difference of the inner and outer diameters of the arm from the rate of deviation thus found, will leave the amount of deflection for the lower side of the arm.*

1394. *Example.*—Let the axle-bed be 42 inches long, the wheels 4 feet 6 inches diameter, the deflection, or total dish, measured from the base of the nave to the plane of the felloes, 11 inches, width of gauge 57 inches over all, and the diameter of the axle-arms $2\frac{3}{4}$ inches and $1\frac{3}{4}$ inch, then

$$(42+11+11)-57=7 \text{ inches},$$

which, divided by the whole diameter, is $\frac{7}{4 \cdot 5}=1.55$ inches, the deviation for the face of the wheel from the perpendicular, or of the axis of the axle from the line of its body. Then half the difference of the diameters of the arm $\frac{2\frac{3}{4}-1\frac{3}{4}}{2}=\frac{1}{2}$ or .5, and $1.55-5=1.05$ inches, is the amount of deflection in 1 foot of the axle-arm.

1395. The axle of broad-dished wheels, with a cylindrical sole, can only be formed straight, or without bend in any direction; any deviation from this is a positive disadvantage; and though the adoption of cylindrical arms for broad wheels has been sometimes recommended, it can only be applicable when the wheels not only stand vertical, but they must have no *dish;* and it is an error to suppose that broad-dished wheels could work with advantage upon straight axles with cylindrical arms.

1396. Of the *practical utility of dishing*, but especially of giving the wheels an inclination outward above, there can be but one opinion—that it is a necessary evil, producing advantages which more than counterbalance any disadvantages that may arise by thus deviating from just theoretical principles. An upright wheel without dish, and running upon a cylindrical axle, is unquestionably perfect in theory; but the various considerations that practice brings to bear on the economy of their application, decides the question in favour of a deviation from strict theory. It has, therefore, been found better to sacrifice a little to utility, and by *dishing* to gain additional strength to the fabric. By inclining the wheel, also, a greater width is obtained in the cart; and the inclination affords another advantage, though certainly not of vital importance, that of throwing off mud from the carriage and the load. The bending and tapering of the axle-arm, consequent upon the dishing, will perhaps appear the most objectionable point in the combination; but this, also, has its compensating quality, for though we have here the friction arising from a conical surface, it is acting against a similar surface revolving round the axle, and the result is only a slight increase of velocity in the revolving surface towards the base of the cone; but as friction is little, if at all, affected by velocity, there will consequently be no increase of the former at the larger end of the axle, as compared with the smaller. In such a case, therefore, the effect is totally different from that of a broad conical wheel rolling upon the extended surface of a road, and constrained to move forward in a straight line. In this case, were the wheel allowed to travel in the circle which the conical surface of the wheel would generate, it would produce nothing beyond the natural resistance of the rolling surface; but being constrained to move right forward, if we suppose the middle part of the tire to have the mean velocity and to roll without sliding, then those parts of the tire lying towards the base of the cone would be accelerated, and would have a tendency to tear up the surface of the road backward, while the parts lying towards the apex of the cone would have the opposite effect—thus producing great and unnecessary friction, all of which is avoided in a conical bush turning round a conical axle.

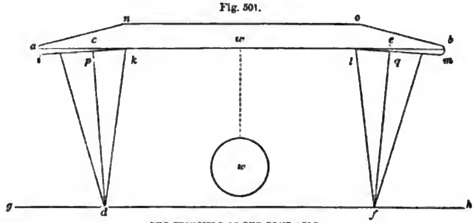
1397. A doubtful practice has long existed in the formation of cart-axles, that of giving the wheels a *gather*, as it is called, in the fore parts. This is done by bending the axle-arms slightly forward, so as to make the wheels run a little nearer to each other in front than behind, the difference varying from 1 inch to 3 inches. There seems no good reason whatever for this peculiarity, though enough of questionable ones are adduced by those who uphold the practice. If any advantage is to be gained from it, the common bent axle, with the cart in yoke, possesses it in a sufficient degree, from the manner in which the horse is yoked to the cart; for the shafts of the cart, taken at the point where the back-chain is attached, are always higher than the axle, and as the axle is attached sufficiently firm to make it move with the cart, and if, when the shafts are horizontal, the wheels are found to be equally distant, before and behind, their relative position will be changed by any movement up or down in the shafts; thus, if the point of the shafts is raised, which is their working position, the wheels will be brought nearer to each other before than they are behind. It is highly probable that this natural result, by being observed in a well-working vehicle, has given rise to the opinion.

1398. In regard to the defective state of the question as to the principles that govern the formation of the axle, and adaptation of the wheels to bring out upon sound data the most perfect action of the wheels on their axle with the minimum resistance, we have, after some investigation of the relation of the parts to each other, and from careful observation of numerous cases, arrived at what we conceive to be a principle, which is sufficient to account for the phenomena under consideration.

1399. The views that have usually been taken of carriage-wheels, when the object was to investigate the effects of the load upon them, would lead us to imagine that the wheel is composed, and not only composed, but continues to act, and to be acted upon, as if it were a number of disjointed parts; but such an assumption is not fact: a wheel built as has been here described, forms one strongly-compacted piece of iron-bound carpentry, wherein every individual part assists in supporting all the others, and the entire frame becomes a rigid structure. Instead, therefore, of supposing that any one spoke that may happen to be in the lowest position at any one instant, and that in a vertical position, supports the whole load, it is more correct to view the wheel as a solid of revolution, generated by the quadrilateral figure *b o p q*, fig. 496. In this figure, formed about the extreme points of the lower or bearing half of the section of a wheel, we have the side *b o* forming the lower side of the axle-arm, and *p q* the sole of the wheel; the whole load on that wheel will be distributed over the line *b o*, and transferred to *p q*, or that part of the wheel which rests upon the ground. If we now conceive the axle *k b o* completed, and the opposite arm supporting its wheel, affording a similar solid, whose section will exactly resemble *b o p q*, upon these two sections the indefinite load on the axle will be equally divided, while the sole of each wheel, or the side *p q* of each, will be pressed to the ground with a force equal to, or little more than, half the load, and the friction caused by this pressure will prevent the sole from all lateral motion on the surface of the ground. If we now consider the effect of gravity upon the sole *p q*, and its supposed opposite wheel, its natural tendency is in the vertical direction, but its *effects* may be diverted from this into any other direction.

1400. *Example.*—In fig. 501, let the straight line *a b* represent a rigid bar supported on two struts *c d* and *e f*, the surface of the ground being represented by *g h*; let a weight *w* be appended to the bar *a b*, gravity will then act in the

Fig. 501.



THE PRINCIPLE OF THE BENT AXLE.

direction *w w*; but the beam and load being supported by the struts *c d* and *e f*, the pressure is borne equally by them, each strut sustaining a pressure of nearly half the weight, together with the beam, and this transferred pressure will be in the direction of the two struts, and not in the vertical line. The construction here represented will come under the denomination of a tottering equilibrium, which it is easy to obviate, but is not of importance under the present consideration; and it will be evident that, besides a tottering equilibrium, the head of each strut will have a tendency to *slide* outward. To prevent this last result, let the lines *i k* and *l m* be drawn at right angles to the struts, and draw also the lines *a n*, *n o*, *o b*; the space included between these lines and *i k*, *k l*, *l m*, represents a longitudinal section of the cart-axle, with bent arms, the lines *i k* and *l m* being the lower side of the arms, which rest upon the bushes of the nave represented here by the same lines *i k* and *l m*. The struts are now supposed to be shortened, and instead of giving their support at *c* and *e*, they support the axle at the points p and q, and being now at right angles to that part of the bar or the axle at which they give their support, the struts have no tendency to slide either outward or inward, so long as the bar itself is prevented by any means from being affected by motion in the direction of its length. If the triangles $d\ i\ k$ and $f\ l\ m$ are now completed, we have figures exactly corresponding to the prism of revolution, when its sides have been extended to r, fig. 496; and it is to be observed, that the triangles $d\ i\ k$ and $f\ l\ m$, fig. 501, being isosceles, the sides $d\ i$, $d\ k$, being equal, and if it is supposed to represent the section of a solid, there is no tendency, though supported on a mere point, to move in one direction more than in the other: hence, if wheels and their axles were constructed to fulfil these conditions, they would possess the greatest possible freedom of action, and be free from all undue pressure either upon the collar of the arm or upon the linch-pins. We consider ourselves warranted, therefore, in offering this as the true principle on which we are to depend for producing the minimum of friction and resistance from the action between wheels and their axles.

1401. It is evident that all wheels having the same quantity of dish, and their axles having the same degree of taper, will come within the condition now specified; and it is to be remarked, that the position of the axle-arms makes no change in the conditions; for whether it be straight, as in those of broad-dished wheels, or inclined in any degree, as in narrow ones, the rule still holds good.

1402. But to bring out the advantages of this principle of formation in its utmost perfection, we have to attend to the following points: That the line of the true or virtual dish of the wheel shall have the same inclination to the face or plane of the wheel, which is at right angles to the axis, as the inclination of the taper on the axle-arm or the bush makes with the axis of the arm or the bush; and what we here call the *virtual dishing* is measured by a line, supposed to be drawn from the middle of the axis of the nave through the middle of the sole of the felloe, as from n to the middle point of the sole $p\ q$, fig. 496, or to the apex r. In the common bushes this inclination is ½ inch on a foot, and as the radius of a wheel is 2½ feet, the amount of virtual dishing would be 1½ inch, which is too little for the stability of the wheel, and should be at least 1 inch on a foot; but this increase of dishing involves the necessity of a like increase in the taper of the axle-arm, which would now be required to have its two ends 1¼ inch and 3¼ inches diameter, and this would be attended with various inconveniences. In practice, however, it is not only desirable, as a matter of opinion, that the wheel should have a tendency, while turning upon the axle, towards the shoulder or collar of the axle, but it is demanded as a matter of safety; for if a linch-pin were to drop out, and the tendency of the wheel to be outward, the wheel would infallibly drop off; but when the bias is towards the shoulder, the wheel may keep its place even in absence of linch-pins. It follows, therefore, that though the method here promulgated is mathematically true in theory, we may, by a slight deviation from the rigid rule, retain the advantages of the combination, and, at the same time, render greater safety to the vehicle. This is accomplished by retaining the bushes commonly in use, and instead of giving the wheel the low dish due to our calculation, let it have a dishing of 2½ to 3 inches, or about 1¼ inch on the foot.

1403. It has been ascertained, from a long series of observations, that with the proportion of 1¼ inch on the foot complete freedom of action is obtained as well as safety; and the existing practice is, in general, happily sufficiently near to the true theory to give every advantage that can be desired; but, nevertheless, we would strongly impress on wheel and axle makers, not to allow the dishing to exceed 3 inches on the wheel when hooped, and to bear in mind, that when the dishing and the taper of the axle are adjusted to each other in the proportion of 1¼ inch on the foot, it matters not, so far as the free working of the wheel is concerned, what degree of bending is given to the axle-arm. It may be straight, or even bent upward, yet the free action of the wheel is not impeded, neither is there any undue strain upon the spokes; for, in the section, fig. 496, in whatever position they stand, the strain or pressure upon them is always one of direct compression, whilst they are mutually aided in sustaining the load by the contiguous parts of the wheel. It must, however, be admitted, that such undue spreading of the lower part of the wheel as would arise from bending the axle upward, would produce a tendency in the wheels to displace the materials of the road, by the thrust of the wheels outwards; but in respect of the action of the wheel upon the axle, all that is requisite is the equality of the angles *b* and *o* of the triangle *b r o*, fig. 496, or, in practice, a near approach to it.

1404. The practice now becoming general of employing *half-round* iron for wheel-tires in fast carriages, and partially so for cart-wheels, removes much of the inconvenience arising from flat iron tires as applied to inclined wheels. Flat iron tires, as will be seen at low *g*, in fig. 496, will at first, if running on perfectly level roads, have the greatest wear on the outward edge, but the tire, in all cases, ultimately acquires the half-round form; and as this form brings the strain more equally upon the sole, it seems desirable that this should be adopted from the first.

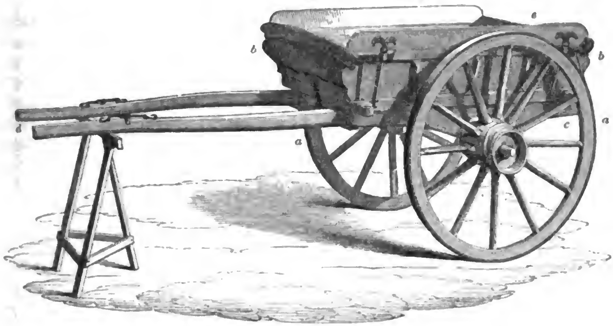
1405. Besides the wheels here described, which are those generally employed on the farm, there has of late years been introduced a variety of forms of construction in malleable-iron wheels, some of which, by a misnomer, have been called wheels on the suspension principle, under which name it was alleged, that, instead of the load being supported on the lower spokes, it was constantly transferred to those above the axle; and the upper portion of the hoop was supposed to bear the load, on the principle of suspension from the hoop as from an arch. In the strict sense of suspension, nothing could be more fallacious than this idea; but in a more limited sense, taking the wheel as a rigid and immutable structure, it has some semblance of truth, for all the parts do bear a portion of strain at all times when loaded, but the parts below the axle must always bear incomparably the largest share.

1406. *Of the Carriage.*—Agricultural carriages are either four-wheeled waggons or two-wheeled carts; and as the Scotch practice, which we incline to think by far the most economical, admits, with very few exceptions, the two-wheeled cart only, the following observations are chiefly confined to that implement.

1407. Though the cart, in general, is a vehicle very much diversified in structure to suit the numerous purposes to which, in a commercial country, it is applied; yet for the purposes of the farm its varieties lie within narrow limits, and may be classed under two principal kinds, the *tilt* or *coup* close-bodied cart, and the close-bodied *dormant* cart; but these, again, vary as to size, forming *single* and *double horse* carts, which are merely varieties of the first. A third and less important kind is the *corn* or *hay* cart, used chiefly in the seasons of corn and hay harvest; and there are others not required on every farm, but are important to some, such as the *cage-cart*, for carrying lambs and other live-stock to market, and the *water* and *liquid-manure* carts already described on page 308.

1408. *The Tilt-cart*, fig. 502, is the most important vehicle of transport on the farm, and is employed for nine-tenths of all the purposes of carriage required in the multifarious operations throughout the year. It is employed to convey

Fig. 502.



THE SINGLE-HORSE TILT-CART

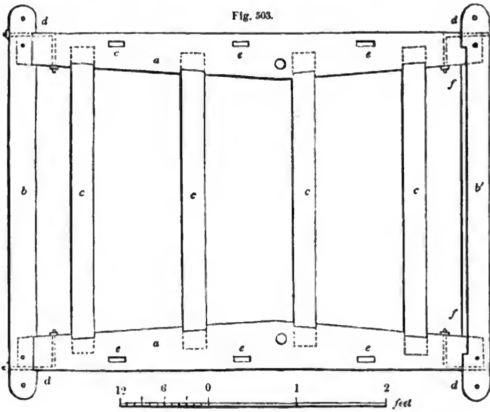
manure of all kinds; to carry stone and tiles for draining, and other materials for various operations; to lead home turnips and potatoes, and to take produce of all kinds to market. For some of these operations the *tilt*-cart is pre-eminently adapted, such as carrying and distributing manures, or other substances that can be safely discharged by tilting.

1409. The *dormant cart*, on the other hand, is sufficiently commodious when substances have to be carried that require to be discharged from the cart by lifting, such as grain in bags, and many other articles requiring to be conveyed to and from the farm.

1410. Fig. 502 is a view in perspective of the common one-horse tilt or coup cart, of a simple and much-approved construction, and consists of the following parts. The wheels *a*, *a*, which are of the usual height, 4 feet 6 inches, are of the dish construction, with cylindrical tread or sole, and are inclined from the vertical to bring them to the standard gauge below. The axle, which is of the bent order, with $2\frac{1}{2}$-inch arms, is only seen as it protrudes through the nave. The body of the cart *b b*, with its bolsters, one of which is seen at *c*, by which it rests upon the axle, and to which the shafts are jointed by means of a joint-rod that passes through the bolsters and the ends of the shafts. The shafts *d* are secured to the body by means of the lock seen in the figure in front; and they are here represented resting upon a trestle to keep the cart upon a level; and lastly, the top sides *e*, *e*, which are fitted to ship and unship as occasion may require. But in order to convey a thorough conception of this importont agricultural vehicle, the following detailed description, with figures, is given in geometrical plan and elevation, and which, except when otherwise stated, are all to one scale, $\frac{5}{8}$ inch to a foot.

1411. *Construction of Tilt-cart.*—The body-frame of this cart is represented in fig. 503, where *a*, *a* are the two main bearers, *b* the fore cross-head, *b′* the back cross-head, and *c*, *c*, *c*, *c* the slots or floor-bearers. The main bearers and cross-heads are made of ash or elm, the bearers $2\frac{1}{2}$ inches in depth, 6 inches in breadth at the point where they are pierced for the caddy-bolts, and $4\frac{1}{2}$ inches at the ends. The fore cross-head is also $2\frac{1}{2}$ inches in depth by 4 to $4\frac{1}{2}$ inches in breadth, and the other $3\frac{1}{2}$ inches in depth by $4\frac{1}{2}$ inches in breadth; and the slots

Fig. 503.



THE BODY-FRAME OF THE TILT-CART.

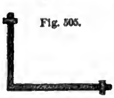
are from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches by $1\frac{1}{2}$ inch, and should always be made of oak. In order to prevent too great a loss of strength in the framework, the mortises for the slots are taken to a depth not exceeding $2\frac{1}{2}$ inches; the tenon of the slots is formed on one side, or single-check tenons, whereby the upper surface becomes flush with the surface of the bearers, and the check is rabbeted into the edge of bearer, as seen in the annexed fig. 504, where *a* is a cross-section of the bearer, and *b* a slot with its tenon rabbeted into the bearer.

Fig. 504.

THE JOINING OF SLOTS AND BEARER.

The tenons at the ends of the main bearers pass, in like manner, only half through the cross-heads, as shown by the dotted lines in fig. 503, and these joinings are screwed and drawn hard up by means of the screw-nuts of the hook-bolts *d*, *d*, *d*, *d*, which are seen on a scale of double the size in fig. 505. The main bearers are mortised at *e e e*, *e e e*, for the wooden standards that form the sides, three on each side, besides the fore and back iron stays, to be afterwards described. These mortises are so placed as to produce a width *within* the sides of 3 feet 6 inches at the floor-line. In framing the back cross-head, which is 1 inch thicker than the bearers, the difference of thickness is brought upward, and the rabbet *f f* is taken out an inch each way, so that its bottom is level with the main bearers, and the ends of the flooring-boards are received into the rabbet, thus bringing the surface of the floor and of the cross-head to one level. To defend this cross-head from the constant wear to which it is subject, it is necessary to inlay upon its surface a bar of iron not less than 2 inches in breadth by $\frac{1}{4}$ inch thick, extending the whole length of the cross-head, or, to make the cross-head $3\frac{1}{2}$ inches thick, and covering it all beyond the rabbet with an iron plate 3 or $3\frac{1}{2}$ inches in breadth.

Fig. 505.



A HOOK-BOLT.

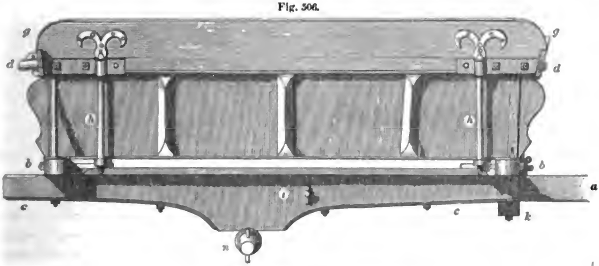
1412. Various modes are adopted for the finishing of this part of the cart, such as the application of an iron bar alone, $2\frac{1}{2}$ inches by $\frac{3}{4}$ inch, in place of the wooden cross-head and its iron fender, in which case the last slot must be put in close upon the iron cross-head, in order to support the ends of the flooring. This method, which is of late introduction, cannot be considered as equal in security and durability to the first-described method.

1413. The body-frame of the cart, finished as above described, varies in its dimensions according to taste and circumstances, but a good medium size for a one-horse cart is 5 feet 4 inches in length, and 3 feet 10 inches in width over all.

1414. The standards of the sides are set with a slope outward of about 3 inches on a foot of height, and the head has usually the same degree of slope, while the door of the cart stands nearly perpendicular, or not exceeding 1 inch of slope outward, making the top dimensions about 5 feet 8 inches in length, and 4 feet 7 inches in width, over all.

1415. Fig. 506 is an elevation of the side of this cart, in which the horse-shafts are broken off at *a*; *b b* is the edge view of the body-frame; *c c* one of the bolsters or limbers, which serve to support and bind the body, while they

Fig. 506.



THE SIDE-ELEVATION OF THE TILT-CART.

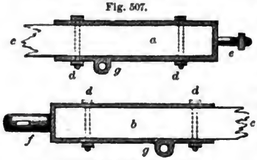
serve also as the medium of connection for the horse-shafts. The bolsters terminate forward at the face of the cross-head, where they are $3\frac{1}{2}$ inches deep and $2\frac{1}{2}$ inches in breadth; at the bearing on the axle they are 7 to 8 inches in depth, and 4 to $4\frac{1}{2}$ inches in breadth; and at their termination behind, where they project 5 or 6 inches beyond the cross-head, they are $3\frac{1}{2}$ inches square.

1416. The bolsters should be made of ash or elm, but, as a means of saving expense, they are frequently made of beech-wood, which, in point of durability in any exposed work, is much inferior to either; but this, and many other inferior substitutes, are, of necessity, resorted to by the agricultural mechanic, to enable him to produce his manufacture at the low market-price of the article.

1417. The end of the axle is seen at *n*, and *i* is the joint-bolt on which the horse-shafts are jointed to the bolsters; *k* is the end of the lock-bar framed into the shafts, and by which they are hooked to the body. The figure exhibits also the three oak standards, which are $2\frac{1}{2}$ inches in breadth at bottom, tenoned into the body-frame *b b*, and at top into the top-rails or shelvements *d d*; these are also of ash or elm, and are $2\frac{1}{4}$ or $2\frac{1}{2}$ by 2 inches. The height of the sides, measuring on the slope, is 17 inches over all, or it is 14 inches inside measure; but this dimension varies more than any other, depending on the purpose to which the cart is to be applied, and many other circumstances. The top-sides *g g* are usually made of deal 1 inch thick; they are 5 to 6 inches in height, and are furnished with the iron arms *h h*, which slide into the eyes *g g* of fig. 507, their lower extremity being also received into eye-bolts fixed into the edge of the body-frame *b b*, fig. 506.

1418. The shelvements are furnished at the extremities with iron mounting, which is seen in plan in fig. 507, on a scale of double the size. In this figure *a* is the fore-end mounting, and *b* that for the back-end or door; *c c* is the wood of the rail broken off; *d d*, *d d* the bolts by which the irons are fastened to the wood; *e* is the screwed tail, by which the forehead-bar is secured to the top-rail, and *f* is the pin upon which the door is passed and secured by a cottar dropt into the cottar-hole at *f*; *g* is the eye forged in the irons for receiving the arms of the top-sides.

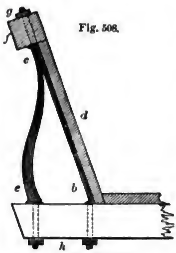
Fig. 507.



IRON ENDS OF THE TOP-RAILS.

1419. The fore as well as the back end of the top-rails are frequently supported by iron stays, to the strap of which the ends of the side-boarding are also secured by rivets; but it is essential that the stay be applied at the back end. Fig. 508 is an end view of the stay, on a scale of double size; *a* is a part of the cross-head broken off, *b c* that part of the stay that supplies the place of a standard: it is 2 inches broad, and $\frac{1}{4}$ inch thick, and the boarding *d* is fixed to it with riveting. The stay proper *e c* is welded to the standard at *c*, where a tail-bolt is formed that passes through the top-rail *f*, and secured by the nut *g*, the bottom of the standard and stay being both also formed into tail-bolts that pass through the cross-head, to which they are secured by screw-nuts *h*, below.

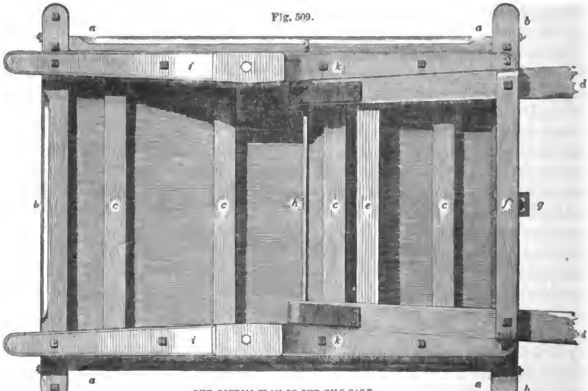
Fig. 508.



THE IRON STAY.

1420. A *bottom plan* of the tilt-cart is represented by fig. 509, in which *a a*, *a a* is the body-frame, *b*, *b*, *b*, the fore and back cross-heads, *c*, *c*, *c*, *c*, the slots of the body-frame, *d d* the shafts broken off, *e* the

Fig. 509.

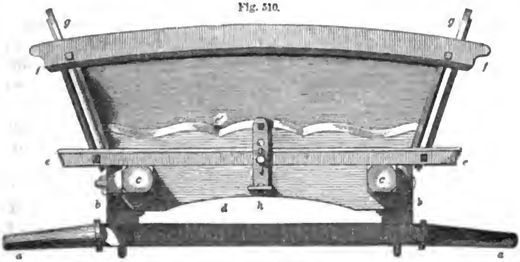


THE BOTTOM PLAN OF THE TILT-CART

slot, and *f* the lock-bar of the shafts, *g* a part of the lock, and *h* the joint-bolt passing through the bolsters *i i* and the ends of the shafts, which are here armed with plates of iron to strengthen and support the wood. In forming and placing the bolsters, attention must be paid to having a proper width in front for the shafts, which should not be less than 3 feet 2 inches between the bolsters at the front, making their over-all width at that point 3 feet 7 inches; at the caddy-bolt *k k* the width over the bolsters may be 3 feet 4 to 3 feet 6 inches, and behind, the precise width is unimportant. Equally so is the width of the shafts at the joint-bolt, as that dimension is adapted to the limbers; but the distance from the bolt to the front of the cross-head is 2 feet 6 inches. The bolsters are secured to the body-frame with four or five half-inch screw-bolts with nuts.

1421. An elevation of the *front* of the cart is exhibited in fig. 510, with the axle attached to the bolsters. *a a* is the axle slightly bent in the arms as for narrow-dished wheels, *b b* the bolsters, *c c* the shafts in section, and *d*

Fig. 510.



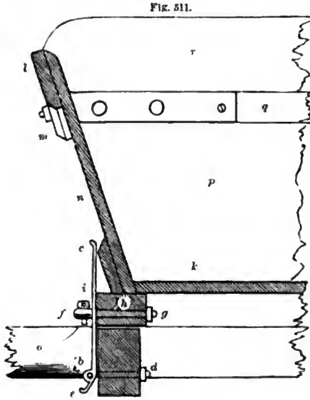
THE FRONT VIEW OF THE TILT-CART.

the lock-bar. The cross-head *e e* is 4 feet 6 inches long, forming part of the body-frame. The lower head-rail *e'* is 4 inches in height, and $1\frac{1}{2}$ to $1\frac{3}{4}$ inch in thickness; it is fitted in between the side-boardings, and spiked or bolted to the cross-head, upon which it lies about $1\frac{1}{2}$ inch within the front edge. The upper head-rail *f f* is 5 feet 2 inches long, $4\frac{1}{2}$ inches deep, and $1\frac{5}{8}$ inch thick; it is secured by the tail-bolts of the end mounting of the top-rails; and here it may be remarked, that in low-priced carts this head-mounting is only a single strap and tail-bolt, in place of the double gland, fig. 507. In a front finished in this manner, with lower and upper head-rails, the upfilling is done with boards standing on end, making it strong, simple, and durable. In connection with this, and above the head-rail, are seen the ends of the top-sides *g g*. The lock *h*, in this example, is an iron bar, 2 inches broad, $\frac{3}{8}$ inch thick, and about 10 inches long; it is hinge-jointed to a bolt near the lower end that is fixed in the lock-bar, and the lock has a bent tail or stop, descending 2 inches below the joint, which permits it to open to a limited extent. It has also several holes of about 1 inch diameter punched in its length, as seen in the figure, and a pin-headed bolt is inserted into the front of the cross-head, projecting about 2 inches from the head. The holes of the lock are adapted to pass easily upon this pin, and when so placed a cottar or forelock is dropped into the cottar-hole of the pin.

1422. The several holes in the lock serve a number of useful purposes; thus, if the load is too heavy forward upon the horse, by shifting the pin one, two, or more holes higher in the lock, the centre of gravity of the load is thrown backward, and lightens the pressure upon the horse; again, in distributing common bulky manures upon the field in small heaps, if the front of the cart is raised and sustained by means of the lock, the manure is more easily discharged with the dung-drag.

1423. Fig. 511 is a section, at double size, of the cross-head and lock-bar, giving a side view of the *lock*. In this figure, *a* is the lock-bar, showing the position of the lock and its joint-bolt; *b c* is the lock, *b* being the joint, and *b d* the bolt; *e* is the bent tail, which allows sufficient range to the motion of the lock on its joint to pass over the lock-pin *f*, before being stopped against the face of the bar. The lock-pin has its tail-bolt *f g* secured into the cross-head *h*, and the cottar *i*, attached by a chain, prevents the lock leaving the pin till it is relieved by the withdrawing of the cottar *i*; *k* is the floor, *m* and *n* the upper and lower head-rail in section; *o* is the horse-shaft, *p* the side-boarding, *q* the shelvements, and *r* the top-side, all broken off.

FIG. 511.



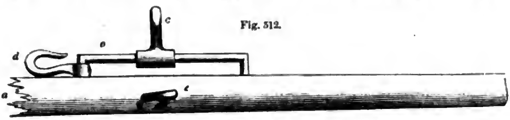
THE LOCK, AND SECTION OF CONTIGUOUS PARTS.

1424. The *shafts* of the tilt-cart are generally made of ash—seldom of oak; but of late years they are frequently made of the American birch and elm, either of which, when fresh and sound, are, from their tenacity and elasticity, well adapted to the purpose. The length of the shaft is about 9 feet 2 or 3 inches, of which $6\frac{1}{2}$ feet go for the yoke; they are worked off and lightened towards the point, and finished according to the taste of the maker. In that part which passes into the cart-body, they are framed upon one slot *e*, fig. 509, which is tenoned into the shafts, and by the lock-bar *f*, which is simply bolted to the shafts; it being of great importance not to weaken the shaft by any mortise at this point, where the greatest strain occurs.

1425. In regard to the scantling of shafts, various opinions have been broached, some advocating the principle that they should be considered in the relation of a beam that has to carry a load, implying that their largest dimension should be in the vertical direction; while much of the general *practice* places them in the other direction, or, at most, making the two dimensions equal. We have already shown in par. 9, that in fixed beams of equal length the strength increases *directly* as their breadth, and as the *square* of their depth. This is an important consideration in the management of beams; but we have grave doubts whether it is desirable to apply the principle to such a movable beam as the shaft of a cart. In stationary beams, rigidity is almost always a chief object; but where one end of the beam is supported on the back of a living and moving animal, rigidity, as appears to us, should be avoided as much as possible, and elasticity made the desirable object. The rigidity of shafts that are formed on the principle of permanent beams, from the severe shocks that they must communicate to the back-chain of the horse, and thence to the whole frame of the horse itself, must be very injurious to the animal, which might be very much mitigated by adopting an elastic medium. Shafts, then, of tough ash, or other elastic woods, we conceive to be the most desirable, and in order to obtain the principle as far as possible, their breadth should rather exceed their depth; and general practice approaches this, as we commonly find such shafts about 3½ inches square at the lock-bar; but let them be made 4 by 3 inches, which is nearly the same sectional area as the former, and the horse would be a gainer, in point of comfort, compared with what he would be were the same shafts placed on edge. Neither would the shafts be much, if at all, more liable to fracture if placed flat-ways; for a single beam that has no elasticity is more liable to fracture from sudden shocks than one of the same absolute strength, but possessing a certain degree of elasticity; and cart-shafts are peculiarly liable to such shocks.

1426. The yoking-gear of the shafts is seen in fig. 512, which is a portion of the off-side shaft enlarged, and broken off at *a*. It consists of the runner-staple *b*, which is from 8 to 10 inches in length, its centre being placed at about 4 feet

Fig. 512.

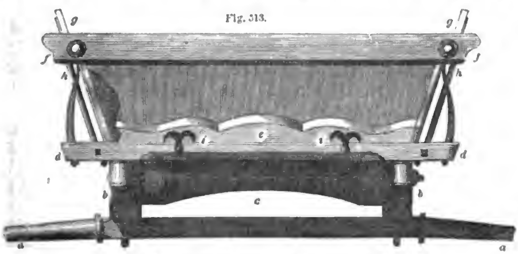


THE YOKING-GEAR OF THE SHAFTS.

6 inches from the lock-bar. The back-chain-hook *c* is fitted to slide from end to end of the staple, and the breeching-hook *d* takes a fixed position on the back leg of the staple; while the draught-hook or staple *e* is generally placed obliquely on the inner side of the shafts, its position there bringing it more directly in the line of traction than if it were attached to the runner-staple, in which position it is sometimes, though improperly, placed.

1427. The *back* view, and *door* of the cart, are seen in fig. 513, where *a a* is again the axle, *b b* the end view of the bolsters, *c* the lock-bar and its connec-

Fig. 513.

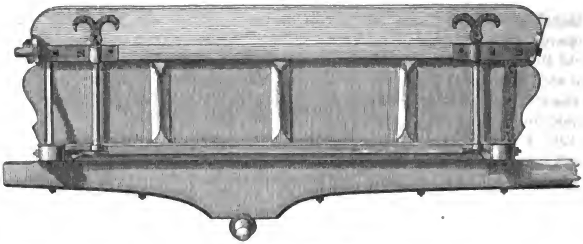


THE BACK VIEW AND DOOR OF THE TILT-CART.

tions, as seen under the body, but at the further end; and *d d* is the cross-head, *e* is the bottom-rail of the door, and *f f* the top-rail, the two being connected by plain boarding standing on end; *g g* are the top-sides, and the arms on which they are supported are seen at *h* and *h*. The door is furnished with the bottom-catches *i i*, which are strongly riveted and bolted to the bottom-rail of the door, their points being received into eye-bolts fixed in the cross-head, which secure the lower edge of the door. The upper part of the door is received upon the iron ends of the top-rails, as seen at *h h*, where it is secured by the cottars dropped into the eyes of the end pins.

1428. *The dormant-bodied Cart.*—Fig. 514 represents a side view of the dormant-bodied cart. It has its body constructed in all respects similar to that of the tilt-cart; description of it is therefore unnecessary, except as regards the

Fig. 514.



THE DORMANT-BODIED CART

shafts. This cart requires no bolsters, but instead thereof the shafts are prolonged backward, taking the place of, and serving most of the purposes of, the bolsters; and at a slight glance, when viewed on the side, the cart has every appearance of a tilt. The entire length of the shafts is about 12½ feet; those parts that fall under the body are fashioned off, as in the figure, similar to the bolsters of the tilt-cart, and of the same dimensions; of the parts before the body, the dimensions and finish are the same as in the tilt.

1429. A great variety of other forms of construction are followed in the formation of the dormant-bodied cart. In many examples the *body-frame* of the tilt-cart is dispensed with, the slots being then tenoned directly into that part of the shafts which fall within the length of the body, and the side-standards are tenoned into the upper surface as in the tilt.

1430. In others, while the slots are framed with the shafts, the side-standards, instead of being tenoned also into them, are attached to the *outside* of the shafts by means of double clasp-bolts. This last is a simple and durable construction, well adapted for the carriage of heavy articles, such as coal and the like; and it gives a greater width of body inside than the other.

1431. In a third form, the slots, instead of being tenoned into the shafts, are simply laid upon them as bearers, and bolted. The side-standards are fixed with clasp-bolts, as in the second variety. In all the three varieties the front of the body is formed by a bottom head-rail bolted to the shafts, the top head-rail being applied as in fig. 510.

1432. It will readily be observed, that of the dormant-bodied cart, par. 1428, the length, but especially the width, is equal to that of the tilt-cart, which is wider than the whole distance between the naves of the wheels, the body-frame being projected a little over these; hence the necessity of the deep bolsters and shafts of these carts. In the varieties of pars. 1429-30-31, the width must be such that they lie between the naves of the wheels; the two varieties, however, with the clasped standards, in pars. 1430 and 1431, acquire a width inside of 3 or 4 inches greater than the variety in par. 1429.

1433. The *two-horse* agricultural cart differs only from the one-horse tilt, fig. 502, and its details, in being of larger dimensions, but especially in depth; the length is also increased a few inches, while the width remains nearly the same, and the limbers are stronger; but all the dimensions are variable, according to the tastes and objects of the owners.

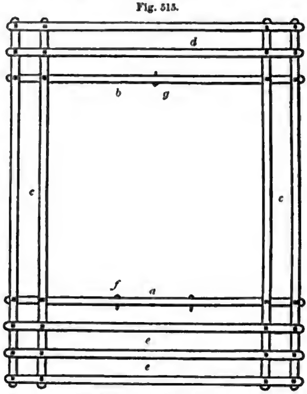
1434. In all carts of the descriptions here noticed, the *cladding or boarding of the floor and sides* is an important point; very fine and straight-grained deal should be avoided, because of its liability to split. Of the woods best adapted for the purpose, we may name the common saugh or willow, the larch, the common Scots fir, and others of the pine tribe; and the more they abound in sound knots, so much the better are they adapted to the purpose, not only preventing the splitting of the boards, but adding to the durability of the material.

1435. The *nails* used for fixing the boarding should always be the common *cart-nail*, which is distinguished from other common nails by its diminished length, increased thickness, and being chisel-pointed—qualities that adapt it for being driven into hardwood, while its thickness gives it the requisite strength to resist the hard usage that such machines are always liable to.

1436. *Corn and Hay Carts.*—Next in importance to the carts already described, come the corn and hay carts, of which there are many varieties; but in many situations, and under certain systems of management, a substitute for these is adopted, in the application of the hay-frame to the common close-bodied cart; and this, though somewhat injudicious in principle, is rather extensively adopted.

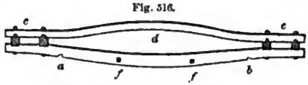
1437. *The Tops.*—The hay-frame, or tops, is a light rectangular piece of framework, represented in plan by fig. 515, and in section by fig. 516. It consists of two main bearers *a* and *b*, which are fitted to lie across the cart, the one *a* to the fore part, slightly notched upon the top-rails, and leaning against the upper head-rail, the top-sides being at the same time removed; the other bearer *b* is fitted in like manner to the back part, leaning against the door. A pair of light side-rails *c* and *c* are applied on each side, crossing the bearers, and notched upon and bolted to them with screw-bolts. These are again crossed by two rails *d* behind, and by three more *e e* in front; and as *e e* project over the back of the horse, they are made arch-form, to give freedom to his motions, the whole being bolted to the longitudinal rails. Fig. 516, the transverse section, exhibits the form of the bearers, and their notchings, *a* and *b* being the top-rails or shelvements. These bearers are about 6 inches in depth by $2\frac{1}{4}$ inches in breadth; the parts projecting beyond the top-rails being tapered off from below to about $3\frac{1}{2}$ inches in depth, and the extreme length 7 feet 6 inches. The section shows also the longitudinal rails *c c*, as cut across by the section and the arched cross-rail *d*. The extreme length, from outside to outside, of the front and back cross-rails is usually about $10\frac{1}{2}$ feet, and the breadth in the same manner about $7\frac{1}{4}$ feet. Both longitudinal and cross rails are from 2 to $2\frac{1}{4}$ inches square, and all made of hardwood, usually ash.

Fig. 515.



THE CORN AND HAY FRAME.

Fig. 516.



THE TRANSVERSE SECTION OF THE HAY-FRAME.

1438. Various methods of securing the hay-frame to the cart are adopted.

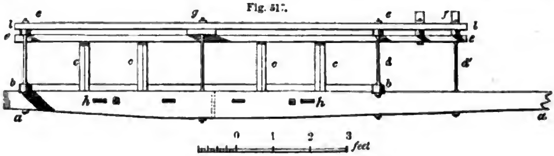
Figs. 515 and 516 exhibit one simple and effective method, by means of the bolts *f f* in the front bearer, which pass through it and the upper head-rail, and by the single bolt *g* in the hind bearer, which passes through it and the door.

1439. Another method is by hook-stanchions of iron, two of which are appended to eye-bolts in the crossing of the fore cross-rail and the inner longitudinal rail, and two similar stanchions are appended in the same manner behind. These four stanchions have their lower ends adapted to hook into eye-bolts fixed in the horse-shafts before, and in the end of the bolsters behind. This method has the advantage of serving as supports to the extremities of the frame, as well as binding it to the cart, though the latter is not so well performed as by the simple bolts shown in the figures.

1440. The price of the hay-frame is from 40 to 50 shillings.

1441. *The Corn and Hay Cart.*—The corn and hay cart, being adapted to a specific purpose, is a more efficient vehicle than the common cart and hay-frame, and is of very simple construction. A side view of this cart is given in fig. 517, and a transverse section in fig. 518 : in these the same letters mark

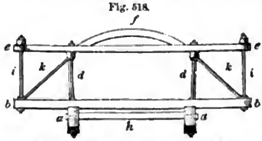
Fig. 517.



THE CORN AND HAY CART.

the corresponding parts of the two figures. Lightness being an object in this construction, the shafts *a a* are usually made of Baltic fir; they are about 17 feet in length, 6½ feet of which goes for the horse-yoke, and the remaining 10½ feet for the body of the cart, measuring over the cross-heads *b b*. The depth at the caddy-bolt is from 7 to 8 inches, tapering forward to 6 inches at the fore cross-head, and onward to 3½ inches at the point; a similar diminution being carried backward, making the depth 5 inches at the back cross-head.

Fig. 518.



THE TRANSVERSE SECTION OF THE CORN AND HAY CART.

The thickness throughout the body is about 4 inches, the yoke part being diminished to 3 inches at the point. The shafts are framed upon the slots *h*, and are further strengthened by two thorough-bolts passing from side to side of the body. The cross-heads *b b* are 7½ feet long, 4½ inches in breadth, and 2½ inches in depth, secured to the shafts by the tail of the iron standards passing through them and the shafts. Each side is formed with four oak standards *c, c, c, c*, and four of iron; two of the iron, *d d*, are those that pass through the cross-heads, serving to bolt them to the shafts; one is placed in the centre, and the remaining one *d′* before the fore cross-head, to support the overhanging parts of the upper works. The inner top-rails are mortised upon the oak standards, and are pierced by the upper extremities of the iron ones. The rails are 12 feet in length, usually made also of fir, and are about 2½ inches by 2 inches. Two upper cross-heads *e e*, together with two arched rails *f*, and a middle or load rail *g*, are next applied. The upper cross-heads, and also the two arched rails, are always made of hardwood—ash or elm. The cross-heads *e e* are about 3 inches by $2\frac{1}{4}$ inches, the arched rails *f* $2\frac{1}{4}$ inches square, and the middle rail *g* 9 inches by 2, the whole being 7 feet in length, and are secured by the extremities of the iron stays passing through them, with screw and nut above. As seen in fig. 518, the ends of the upper cross-heads are supported by an iron standard *i i* planted near the end of the main or lower cross-head; and between each of these and the principals *d d*, a diagonal stay *k k* is applied, to give lateral support to all the upper works. The outer top-rails *l l*, fig. 517, are of the same dimension as the upper cross-heads, and are supported on the extremities of the cross-rails, along with which they are secured to the outer iron standard by screw-nuts, the bearing on the middle rail being secured by a simple screw-bolt. The extreme breadth over these outer rails is about 7 feet.

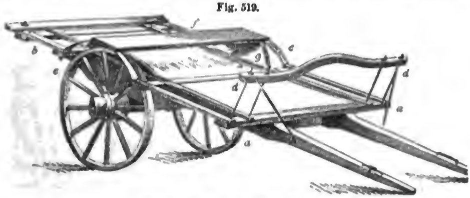
1442. The yoke-gear of this cart is of the same construction as that of the tilt-cart, fig. 512; and for the purpose of collecting any shaken-out grain, the body is usually close-floored, besides having a ledge-board of 3 or 4 inches high running along the inside of the standard, as seen from *b* to *b*, in fig. 517.

1443. The corn and hay cart is seldom furnished with axle and wheels exclusively attached to it, but is adapted to those of any of the common carts, upon which it is placed when required.

1444. In piercing the shafts for the caddy-bolts, the same rule is observed as for those of the tilt-cart; taking the extreme length over the cross-rail behind the front arched rail *f*, fig. 517, and dividing this in two equal parts, setting off $\frac{1}{14}$ of the whole length backward from the middle point, gives the position of the bolts.

1445. *Robertson's Improved Corn and Hay Cart.*—A corn and hay cart, simple in construction, but possessing complete efficiency and greater safety than fig. 517, was contrived by a farm-servant, by name Robert Robertson, and was introduced in 1832* in the west of Fifeshire and neighbouring counties, and of which fig. 519 is a view in perspective, with its wheels and axle in full working state. The shafts and body-frame of this cart may be considered as identical

Fig. 519.



ROBERTSON'S IMPROVED CORN AND HAY CART.

with fig. 517, which, without the upper works, is the simple dray-cart. Upon this body-frame is placed the fore and back cross-heads *a a* and *b*, projecting beyond the body, their extreme length being $7\frac{1}{2}$ feet. Lighter cross-rails are applied, one before and another immediately behind the wheels, and the whole bolted to the shafts. Upon these cross-rails are laid a longitudinal rail $3\frac{1}{2} \times 2\frac{1}{2}$ inches on each side, and not more than 2 inches beyond the body-frame, and two similar portions of longitudinal rails are also laid on each side, extending from the fore and back cross-head to the wheel-rails; over these longitudinal rails is laid another light cross-rail behind, and the parts all secured

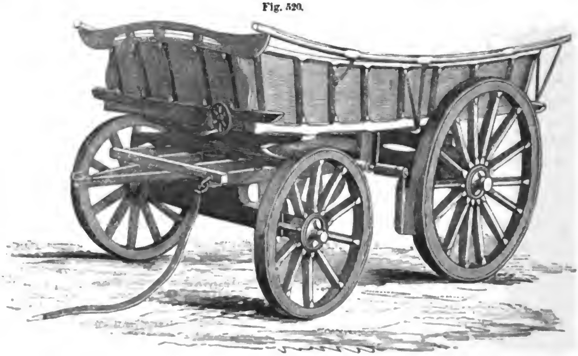
* *Prize Essays of the Highland and Agricultural Society*, vol. xi. p. 395.

with bolts. A light frame *d d* is raised upon the fore cross-head *a a* to a height of 2 feet, with two iron stanchion-rods at each, and these are surmounted by an arched rail, which is supported against the pressure of the load by two iron stays from the shafts. The outer longitudinal rails, being cut by the wheels, are connected again by the arched iron bars *e* and *c*, which are bolted at the ends to their respective rails, and these are connected by the broad cross-rail *f*, the arches rising sufficiently high to allow the wheels to have freedom to turn below the rail *f*. A side-board *g* is also raised on each side upon the body-frame, and under the arch-rail *e*, extending a little before and behind the wheels, thus preventing the load from coming in contact with the wheels. The body-frame is floored over in the usual manner, and the space between the body and the inner longitudinal rails is filled up with hinged flap-boards, which are required about 4 inches broad, thus preventing the loss of grain that may be shaken out in the cart.

1446. Carts of this construction possess several advantages: from their simplicity is derived cheapness; and from the load assuming its full breadth over nearly the whole floor of the cart, at the lowest possible position, the centre of gravity of the whole load will be very considerably lower than in that of the hay-cart, fig. 517, and still more so than on the hay-frame, fig. 515. The low gravity produces greater stability, and reduces the risk of upsetting, besides affording a greater facility of loading. There is also the advantage of its easy conversion into an open dray-cart for carrying timber or the like, which is done by unbolting the cross-heads and rails, and removing the upper framework in a mass. The removal of the upper framework is frequently connected with the common corn and hay cart, by having the whole of its upper works based upon two longitudinal rails corresponding to those of fig. 519; and these being attached to the two main cross-heads, the whole upper works can be lifted off the body-frame, and again secured by the insertion of four bolts.

1447. *The English Farm-Waggon.*—In fig. 520 we give a perspective figure of the waggon manufactured by Mr Crosskill, of Beverley. The length of the

Fig. 520.



CROSSKILL'S ENGLISH FARM-WAGGON IN PERSPECTIVE.

body over all is 10 feet, the width 3 feet 10 inches, the height of the front wheels is 3 feet 4 inches, and that of the hind, 4 feet 9 inches. The waggon is constructed either with pole or shafts, and is provided with a break easily regulated by a winch-wheel in front, as shown in the figure.

1448. The waggon has never yet found its way upon a farm in Scotland, nor is it likely ever to find it, as it seems to possess no decided advantage over the common cart. It is true that the waggon can convey a very heavy load, and it bears no stress upon the horse's back; but a well-balanced load upon a cart bears no undue strain upon a horse's back; and it has already been proved, in par. 496, that the horse draws a load all the better and the steadier by bearing a proportionate share of the load upon his back.

1449. Hay, being the most bulky load of the farm, is the most trying one for horses, and yet we have seen 100 stones of hay—which in Scotland weighs nearly a ton—delivered by a single horse at several miles' distance in such a hay-cart as fig. 517, and $1\frac{1}{2}$ ton is no uncommon load of hay for a pair of horses in a double-horse cart.

1450. A waggon, therefore, that would carry a heavier load than that just stated, would not be of particular service on a farm in preference to a cart, inasmuch as the horses would either be overstrained by it, or their number would require to be increased; and besides, a large and heavy load occupies too long time in loading and unloading for horses to be standing idle in the yoke.

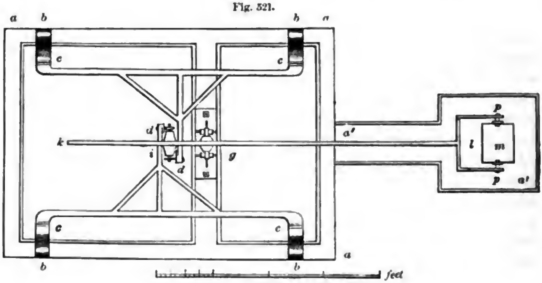
1451. On a comparison between a waggon and cart, as the means of conveying all kinds of agricultural produce, it cannot be denied that the very appearance of the cart at once determines it to be the more handy and easily-managed machine.

1452. *The Cart Steelyard.*—We have in par. 1352 made reference to weighing-machines for in-door purposes, and in particular for those of the barn. We now describe another weighing-machine, the cart-steelyard, which, by judicious arrangement, may be applied to many other objects in the weighing department. It is not in the weighing of carts, nor of grain alone, that the farmer should be interested; there is nothing that the farm produces, nor that is received or delivered upon it, that is not deserving of being weighed and registered. Not that every particle of produce, nor every cart-load of manure, should be precisely weighed, but large samples of both might be taken, upon which a fair average could be struck; but in many cases, such as the produce of a particular field that has been undergoing a certain routine of management, the whole produce may be taken with comparatively little trouble if the means of doing so were at hand, and the certain result would be a source of high satisfaction to the active and industrious farmer. In all manufacturing establishments, the raw material consumed is carefully ascertained as well as the finished goods. Farming is but another name for a manufacture of goods, the most important of all others—the staff of life; and why should the farmer not adopt the same correct system in conducting the details of his business, which is every day followed in the establishments of those who are employed probably in the re-manufacturing of his produce? It is not meant to be urged, that he could gain anything directly by adopting the practice of weighing all his outgoings and incomings of manures, produce, &c.; but the satisfaction of knowing at all times what he is putting into this field, or drawing from that, in tons and hundredweights, is a matter of no small importance; and, what is more, it would form part of a system based upon close attention and vigilance towards the details of the business in hand, and which vigilance and attention are the mainstay of all sound management.

1453. The cart-steelyard or weigh-bridge, which is here exhibited by fig. 521, a geometrical plan—fig. 522, a longitudinal section—and fig. 523, a transverse section, is a machine in which a combination of levers is employed to effect, in a commodious way, the weighing of bodies of considerable weight, and which would require the common Roman steelyard of most inconvenient dimensions, or a balance equally cumbrous, besides the inconvenience of a great mass of movable weights. The combination consists of two double-fulcrum levers of the second order, combined with a single lever of the first order. The relation of the arms of the double-fulcrum levers are $3\frac{1}{2}$ to 1, and of the single lever 8 to 1, making the ultimate ratio 28 to 1, so that every cwt. placed upon the platform of the machine is balanced by 4 lb. on the scale-board attached to the second lever.

1454. In describing the construction of this compound steelyard, we have in fig. 521, the ground or geometrical plan, the bed-frame *a a a a*, which is 6 feet in length by 4 feet in breadth, the bars being about 5 inches broad and 1 inch

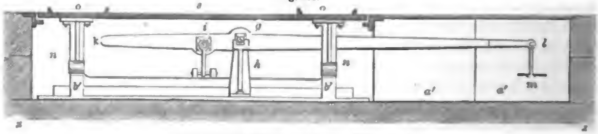
Fig. 521.



PLAN OF THE CART-STEELYARD.

thick, except the middle bar, which is 6 inches, the whole surrounded by a stand-up flange 2 inches in height. This frame is laid in a pit formed of masonry, *x x*, figs. 522 and 523, adapted to the size of the frame, and having the surface of its foundation-course laid level, with a footing inwards, at a depth of 1 foot

Fig. 522.

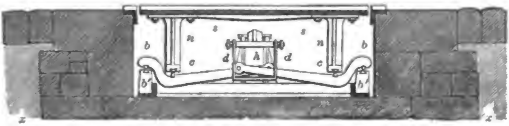


LONGITUDINAL SECTION OF THE CART-STEELYARD.

8 inches under the surface of the ground, sufficient to bear the sole-frame, and upon which it requires to be solidly bedded. Four blocks *b′ b′* are cast upon the upper surface of the frame, standing at a height of 6 inches above it, as seen at *b′ b′*, in fig. 523; they are faced on their top-surface with a cradle of steel, forming the dead fulcra of the levers *b b*.

1455. The two first levers *b c d*, *b c d*, fig. 521, seen also in profile at *b c d*, *b c d*, in fig. 523, are so formed in the horizontal direction as to bring their points of bearing at *b*, *c*, and *d* to the requisite position; and in the vertical direction, as seen in fig. 523, to bring the *centres* *b*, *c*, *d* into one plane. The *centres* of these two levers at *b* and *c* are steel pieces, worked off to a knife-edge, and fixed into a dovetailed seat in the levers, while that at *d* is a steel pin passing through the end of the lever, the *centre* being formed on the pin at one side, as seen in fig. 521; and when the levers are duly placed, their ends *d* pass each other about 6 inches, being thus suited to the *centres* of the second lever. The second lever *k l*, seen in figs. 521 and 522, has its main centres *g* supported upon the

Fig. 523.



TRANSVERSE SECTION OF THE CART-STEELYARD

two arms of the standard *h*, raised upon the middle bar of the sole-frame, as seen in figs. 522 and 523. From the centre *g* to *i* the distance is 8 inches, and from *g* to *l* it is 64 inches, or 8 to 1; the extremity *i* to *k* being for the purpose of adjusting the equilibrium of the machine. Upon the centres *i*, of which there are one on each side of the lever, links are appended, which, in their lower *bend*, receives the centres *d d* of the two first, and the extremity *l* is formed into the fork *p p*, fig. 521, upon the centres of which the scale-board *m* is suspended.

1456. The chamber *a′ a′*, in which the second lever vibrates, is of the same depth as the main pit, and may be formed with masonry, or a casing of cast-iron, with covering plates to enclose it. The platform *s s*, which is left out in fig. 521, but is seen in profile in figs. 522 and 523, is also a frame of cast-iron, whereof the end bars are 15 inches in breadth, with raised ledges, as seen at *o o* in the section, fig. 522, to guide the cart-wheels when being placed upon the platform *s*. Four pendant pillars *n*, figs. 522 and 523, are bolted to the lower side of the platform *s*, and steel cradles are fixed in their lower ends, which are adjusted to bear equally on the centres *c* of the first levers. When the platform is thus placed on its centres, and the scale-board suspended on its centres at *p p*, fig. 521, if the equilibrium is not perfect, it is to be adjusted by adding to or taking from the back end of the second lever. A light cast-iron frame is also laid into the masonry round the edge of the pit, having guides to lead on the cart-wheels, and also studs projecting inward, coming under the platform at the wheel-tracks —these last serving to bear not only the weight of the platform when unloaded, but to receive the shocks of the load when coming upon it, thereby saving much of the tear and wear of the centres.

1457. In this form of weighing-machine, it will be observed that the platform can have no lateral motion, which would be a defect if it had a great range vertically; but this being extremely small, the want of lateral motion does not affect the accuracy of the indications. In those machines having slight lateral motion, the principles of the levers are the same as here described—the chief difference being this, that the platform is suspended upon links, to accommodate which the pillars *n n* are lengthened downwards, and hooked under the first levers, so as to rest upon the links suspended from them.

1458. By using a movable pen of wood or iron hurdles upon the platform, cattle and sheep may be easily and quickly weighed upon this machine.

1459. A more elaborate form of the machine is in frequent use where the business is extensive; it consists in the application of a third lever, which is so arranged as to stand within doors in the weigher's office. This lever is graduated, so that *one weight* adapted to slide along upon its edge gives the result of any weight that comes upon the platform down to a certain denomination, suppose stones, or one-eighth of a hundredweight; and by the aid of a second and smaller weight, properly adjusted, the result in pounds may be obtained, and so on.

1460. The prices of cart-steelyards, as here described, range from £15 to £25.

1461. SECTION FIFTH.—*Straw-Cutters.*

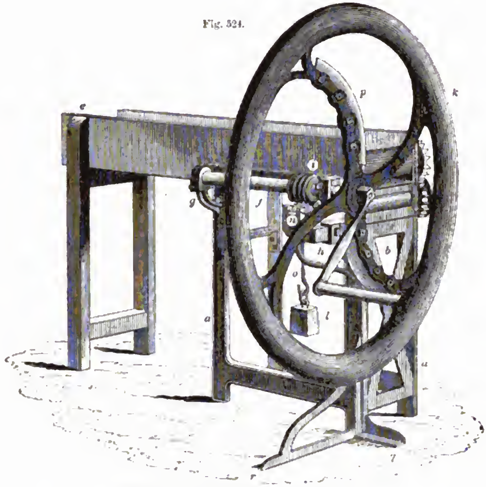
1462. The importance of supplying cut fodder to cattle being now fully established, machines to bring the material to the desired state of division are essential parts of farm mechanism. We shall, in the present section, describe and illustrate one or two specimens of this class of machines, known generally as *chaff*-cutters—a title, however, which is a misnomer, as the machines are cutters of straw, not of chaff: they cut the straw into small pieces like chaff. We therefore prefer and use the title *Straw-Cutters.*

1463. There are several orders or classes of straw-cutting machines, and of these we propose to select for illustration that known as the *disc.* This forms, we think, the most important order of this machine, and is that also which is for the most part employed in England. The principal feature, the cutting-knife, fixed upon the fly-wheel, is invariable, except that it sometimes carries one, at other times two knives. The machinery or details are exceedingly varied. In some, it is adapted to cut of various lengths by means of ratchet-wheels and lever-catches applied to the motion of the feeding-rollers, and at the same time to move the substance forward only in the intervals of the stroke of the knife; in others, the motion of the straw at intervals only is attended to; in a third, a continuous motion of the straw is deemed sufficient: and these varieties of motion are produced by other and various arrangements of spur, bevel, and screw gearings.

1464. *The Disc Straw-Cutter with Convex Knives.*—The machine selected for illustration is one in which two knives are employed, and which gives to the substance to be cut a continuous motion forward. The figure here representing this is taken from a machine manufactured by John Anderson and Son, founders, Leith Walk, at a price of £10, 10s. Fig. 524 is a view of this machine in perspective. The chief parts of the framework are of cast-iron, consisting of a frame *a a* on each side of the machine, which are supported transversely by the truss *b*. The front parts of the side-frames extend upward and form the feeding-roller frame. The cutting-plate is attached in front of the latter portion of the framework, and is dressed truly off for the passage of the knife over its face. The feeding-trough *e* is connected in the fore part to the roller-frame, and along its bottom to the upper edge of the side-frames. The back end of the trough is supported in a light wooden frame. The principal shaft *f* is supported on two projecting brackets *g* and *h*, and upon it is mounted the single-thread screw *i* and the fly-wheel *k*; on the extreme end also of the shaft the winch-handle *l* is attached. A bracket carries one end of a small shaft, on which the screw-wheel *n*, of 21 teeth, is mounted, and is turned by means of the screw when the fly-wheel is put in motion. On the opposite end of the small shaft *n* a spur-wheel is also placed, and acts upon another of equal diameter placed on the axle of the lower feeding-roller. The lower as well as the upper roller are furnished with the usual long-toothed pinions, for admitting of the rise and fall of the upper roller. The upper roller is supported in a light frame that rises and falls in a slide of the roller-frame, and this is acted upon by a lever and weight, of which the hook only is seen in the figure at *o*. The cutting-knife *p* is 18 inches in length, and 4 inches in breadth. It is firmly bolted upon the arm of the fly-wheel *k*, and its cutting edge, which is convex, is so formed that every successive point, in passing the edge of the cutting-plate, forms equal angles with the edge of that plate.

1465. In many of the disc machines, the cutting edge of the knife is concave, formed on the same principle of equal angles, and, in effect, is the better of the two.

Fig. 524.



THE DISC STRAW-CUTTER WITH CONVEX KNIVES

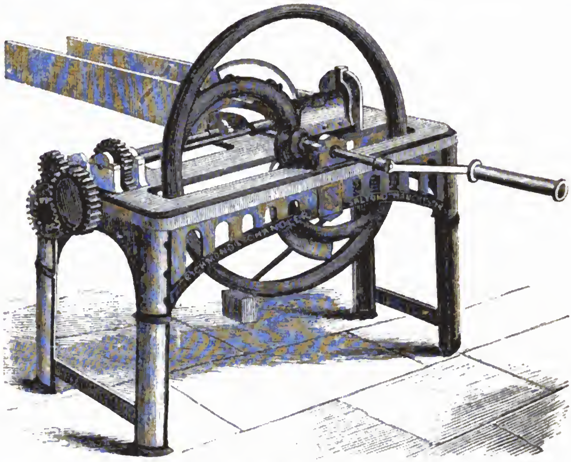
1466. The dimensions of the principal parts of this machine are as follows: Width of the frames 14 inches; length of cast-iron frames 30 inches, and height 3 feet; length of feeding-rollers 12 inches, and their diameter 4½ inches; length of feeding-trough 5 feet, and width 12 inches. The fly-wheel is 4 feet 3 inches diameter, and the height to its centre is 3 feet. From the entire weight of the fly-wheel being supported at one angle of the frame, the spreading brackets *q r* are attached, to give the machine stability.

1467. *Richmond and Chandler's Straw-Cutter.*—Of the various forms of straw-cutters used in England, perhaps the best known and the most highly esteemed is that manufactured by Messrs Richmond and Chandler of Salford, Manchester. The leading peculiarity in this form of machine is the employment of toothed rollers, which are self-feeding, and are not liable to choke. The prevention of choking, and rendering the machine nearly self-feeding in its operation, are two advantages of immense importance. We give more than one form of this machine, which, from the utility of the above features, the compactness of the arrangements, and the admirable workmanship which usually characterises the specimens sent out by the manufacturers, may be cited as a good example of what agricultural mechanism ought in all cases to be.

1468. In fig. 525 we give a perspective view of the machine, and in fig. 526 a plan, drawn to a scale of 1 inch to the foot; and in fig. 527, part section, full size, showing the form of the teeth of the rollers.

1469. The framing is entirely of cast-iron, well fitted, stayed, and securely bolted together, so as to insure steadiness of working. The height of the bed-plate of the frame from the ground-line is 2 feet 8 inches; the length of the bed-plate *a a a*, fig. 526, is 3 feet $3\frac{1}{2}$ inches; its breadth at the narrowest part

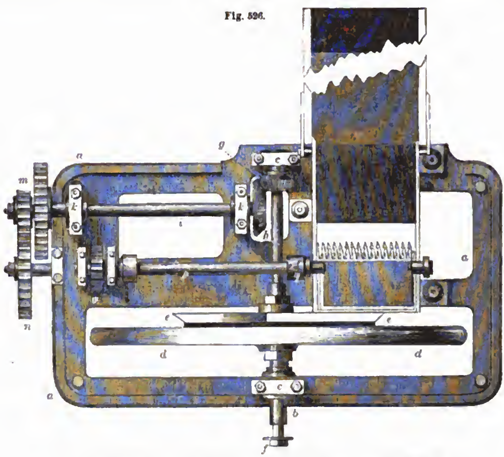
Fig. 525.



RICHMOND AND CHANDLER'S STRAW-CUTTER IN PERSPECTIVE

1 foot $9\frac{1}{2}$ inches, and at its broadest part 1 foot 11 inches. The fly-wheel shaft *b*, $1\frac{1}{8}$ inch in diameter, is placed across the centre of the machine, and

Fig. 526.



PLAN OF RICHMOND AND CHANDLER'S STRAW-CUTTER—SCALE, 1 INCH TO THE FOOT.

revolves in steps or pedestals, *c c*, bolted to the sides of the bed-plate. The bed-plate is relieved by a vacant space to the front, 6 inches wide and 2 feet 10 inches long; in this the fly-wheel *d d* and knives *e e* attached revolve. The diameter of the fly-wheel is 2 feet 9 inches. Motion is given to it by a handle fixed at the outer extremity at *f*. At the other end of the fly-wheel shaft a mitre or bevel wheel *g* is keyed on, 3¼ inches diameter, engaging with a bevel-wheel *h*, 5 inches diameter, fixed in the end of a shaft *i* at right angles to the fly-wheel shaft, revolving in bearings *k k*. On the outer extremity of this shaft *i*, a pinion, 2¾ inches diameter, is keyed; this engages with a spur-wheel *l*, 8½ inches diameter, revolving on a stud fixed to the framing of the machine. To the centre of this spur-wheel *l*, a pinion *m*, 3 inches diameter, is fixed, engaging with a spur-wheel *n*, 8 inches diameter. This is keyed on the end of a shaft *p* parallel to the shaft *i*; and, passing below the bed-plate at its farther extremity, a spur-wheel or pinion, 4¾ inches diameter, engages with a similarly sized wheel *o*, keyed on to the shaft *p*, which gives motion to the upper roller. To admit of the rise and fall of this roller, according to the thickness of the layer of straw passing through, a swing-joint *q* is provided to the shaft *p*. The width of the feed-mouth is 9 inches, rising from 1½ inch to 4 inches; the length of the feeding-trough is 4 feet. The form of the knives is shown in the perspective figure; it is that of a differential scroll, and gives a continuous and uniform cut during the revolution of the fly-wheel.

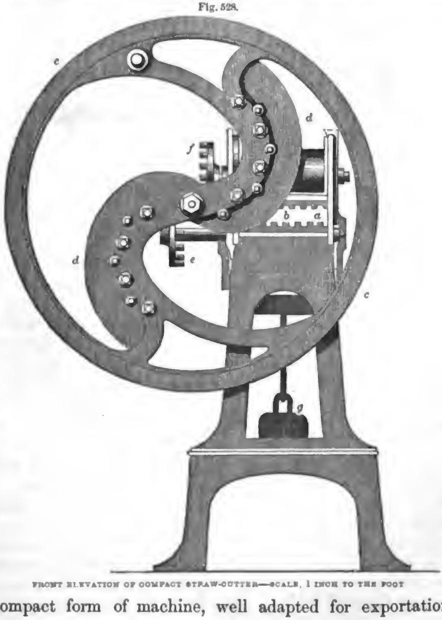
Fig. 527.

ROLLER-TEETH OF STRAW-CUTTER

1470. The price of this machine, adapted for hand or power, is £7. The cost of a pulley, where it is to be driven by power, is 9s.; change-wheels to vary the length of cut, 6s. 6d. per pair.

1471. *Richmond and Chandler's Compact Straw-Cutter.*—In figs. 528 and 529 we give two views of an exceedingly compact form of machine, well adapted for exportation,

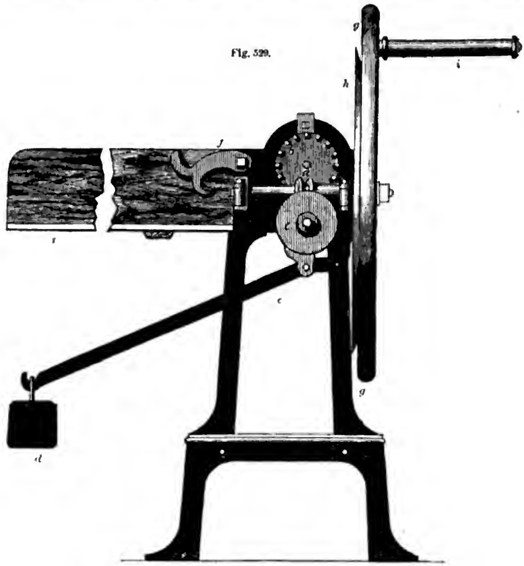
Fig. 528.



FRONT ELEVATION OF COMPACT STRAW-CUTTER—SCALE, 1 INCH TO THE FOOT recently introduced by the same firm, and constructed on the same principles as that described in fig. 525.

1472. Motion is given to the feed-rollers through the medium of a single-thread worm *a*, fig. 529, acting on the face-wheels *b* and *c*; the pressure on

Fig. 529.



SIDE ELEVATION OF COMPACT STRAW-CUTTER—SCALE, 1 INCH TO THE FOOT

the feed-rollers *a* and *b*, fig. 528, being regulated by the weight *d* on the lever *e*, fig. 529. The feed-box is at *f f*, *g g* the fly-wheel, *h* the knife, *i* the handle. In fig. 528, *c c* the fly-wheel, *d d* the knives, *e* and *f* the face-wheels, *g* the weight. Fig. 528 is a front, and fig. 529 a side view—the scale to which they are drawn being 1 inch to the foot. Price of this machine, £3, 15s.

1473. *Gorse or Whin-cutting Machine.*—By a change in the gearing of the straw-cutting machine, fig. 526—the pinion on the end of the shaft *i* having four more teeth—it is used as a gorse-cutter, the toothed rollers serving to crush and bruise the gorse before the knives cut it.

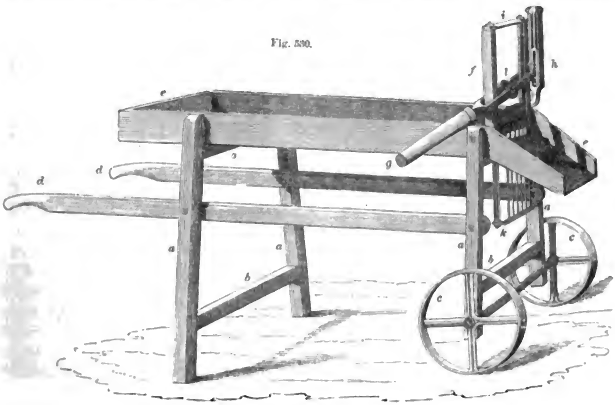
1474. Section Sixth.—*Turnip-Slicers, Root-Graters, and Root-Washers.*

1475. *Turnip-Slicers for Sheep.*—Machines for slicing roots, and particularly for the turnip, are constructed in a great variety of forms, but may be classed under two leading groups—those that cut the turnip simply into circular discs, as generally adopted for the feeding of cattle, and those that cut at one operation into oblong rectangular pieces or parallelopipedons, commonly practised for feeding sheep—forming a somewhat more complicated class of machine. Turnip-slicers for sheep may be again subdivided into lever and revolving machines; and of the many varieties under these forms, there are the stationary, the portable, the wheelbarrow, and what may be called the locomotive machine; the locomotive being rendered so by its attachment to a cart, and by its own motion thus communicated, performs the operation of slicing while it travels over the field.

1476. The first introduction of the turnip-slicer is, like many other equally useful inventions, lost in obscurity, but it is most probable that, like the cultivation of the root itself, it originated in England; and it is likewise probable that the first attempt was the simple *chopper* still used to chop turnips for cattle. It appears uncertain whether the lever or the revolving slicer came first into use, as does also the time of their introduction. But we have an authentic record of a premium having been offered in 1806 by the Board of Trustees for the Encouragement of Arts and Manufactures in Scotland, for a revolving turnip-slicer. This was awarded to John Blaikie, carpenter to the late Lord Polwarth, Harden, Berwickshire, which is believed to have been the earliest application of that form of the machine in Scotland.

1477. *Lever Turnip-Slicer for Sheep.*—The first of the sheep turnip-cutters that we shall notice, is one of the lever form, but in its mechanical construction may be very aptly called the gridiron turnip-cutter, and is represented in an entire form in fig. 530, which is a perspective view of the machine. It consists of a wooden frame supporting a trough, together with the cutting apparatus.

Fig. 530.



THE LEVER TURNIP-SLICER FOR SHEEP

The frame is formed of the four posts *a a a a*, which are $2\frac{1}{4}$ inches square. The front pair stand 15 inches in width, over all at top, the hind pair 19 inches; in both they spread a little below, and are separated to a distance of about 34 inches. Each pair is connected by cross-rails *b b*, and they are connected longitudinally by the bars *d d*, $4\frac{1}{2}$ feet long, which form also the handles of the wheelbarrow, being bolted to the posts at a suitable height for that purpose; their scantling is 2 inches by $1\frac{1}{2}$ inch. A pair of wheels, *c c*, of cast-iron, 9 to 12 inches diameter, fitted to an iron axle which is bolted to the front posts, gives it the conveniency of a wheelbarrow. The trough *e e*, into which the turnips are laid for cutting, is 4 inches deep and 3½ feet long, besides the sloping continuation *e* of it in front of the cutters, for throwing off the sliced turnips. The cutting apparatus consists of a grooved frame of iron *f*, in which the compound cutter moves up and down by means of the lever handle *g*. A forked support *h* is bolted by a palm to the further side of the wooden frame, and at the extremity *i* of the fork a swing link is jointed. The lower end of the link is jointed to the extremity of the lever, which is likewise forked, forming its fulcrum; and the gridiron-cutter *k* is also jointed by its top-bar to the lever at *l*. While the point *l*, therefore, of the cutter moves in a parallel line by its confinement in the grooves of the frame *f*, the fulcrum is allowed to vibrate on the joint *i* of the swing link—thus allowing an easy vertical motion to the cutter through the full range of its stroke.

1478. For the better illustration of the cutting apparatus, the following figures are given on a larger scale. Fig. 531. is a front view of the cutter-frame, and fig. 532 a horizontal section of the same, including that of the

Fig. 531.

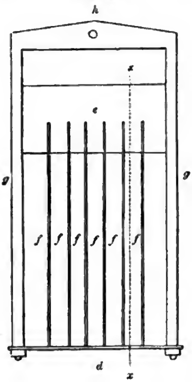


Fig. 533.

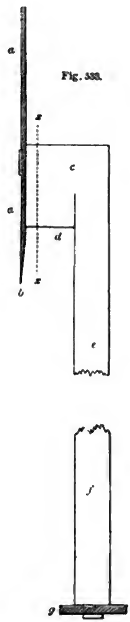
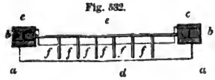


Fig. 534.

Fig. 532.



THE FRONT AND SIDE VIEWS OF THE CUTTERS OF THE LEVER TURNIP-SLICER.

grooved frame *f*. In fig. 532, *a b c* is a section of the grooved frame, with the cutter-frame set in the grooves. The grooves are ½ inch wide, and the cheeks of the frame 1½ inch by ½ inch, making the parts *a b c* 1½ inch square; *a d a* is the bottom bar of the cutting-frame, 1 inch broad and ¼ inch thick, kneed at the ends to receive the lower ends of the cutting-frame; *e* is the edge view of the slicing-knife, as fixed in the cutter-frame, 4 inches broad by ⅛ inch thick, and *f f f f f f* are the vertical or cross cutting-knives, also as seen from above. In fig. 531, *d* again marks the bottom bar of the cutter-frame, *e* is the slicing-knife, and *f f f f f f* the shanks of the cross cutting-knives; these are riveted at top into *e*, and at bottom into *d*; *g g* are the side-bars of the cutter-frame, ¾ inch by ½ inch, into which the knife *e* is riveted, and to which the bar *d* is attached by screw-nuts. The top bar *h* welded to *g g* swells out in the middle, where it is perforated for the joint-bolt of the lever, as seen at *l* in fig. 530, and forms as a whole the gridiron cutter.

1479. Figs. 533 and 534 are views of the knives on a still larger scale. In fig. 533, together with the portion *f* broken off, *a a b* is a cross section of the slicing-knife, and *c d e f* a cross cutting-knife, with its shank; here *a d* is the cutting edge, *c* being the body, and *e f* the shank of the knife. The length of the cutting edge *a d* may vary from ½ to 1 inch, according to the practice of the feeder, the shank *e f* being about ½ inch broad, and the whole ⅛ inch thick, except the cutting edge, that alone being sharpened and steeled as well as the edge of the slicing-knife. Fig. 534 is a section of a cross cutting-knife on the line *x x*, of fig. 533, together with a part of the shank *e*.

1480. The whole length of the cutter-frame, fig. 531, is about 20 inches, apportioned thus,—from the bottom bar *d* to the edge of the slicing-knife, 12 inches; breadth of the knife, as before, 4 inches; and from the back of the knife to the top of the frame, 4 inches. The width of the frame over all may be 9 inches, and the cross-cutters set at from 1 to 1½ inch apart. The grooved frame must of course be constructed to receive and admit of the range of stroke of the cutter-frame.

1481. It is to be remarked, that the slicing and cross-cutting is performed with this machine by one operation, the slicing edge being only ½ inch in advance of the cross-cutters, as at *b* in fig. 533.

1482. In operating with this machine, the trough *e*, fig. 530, is filled with turnips, and the operator lays hold of the lever *g* with the right hand, while in his left he holds a short baton. Having raised the lever, and with it the cutter-frame, he pushes a turnip with the baton against the gridiron, and bringing down the lever, the knives cut off a slice, and divide it into oblong pieces; these may partly remain between the backs of the cross-cutters until the succeeding stroke is effected, when the several portions of this slice will discharge those of the first, and so on, into any vessel placed below the sloping part of the trough *e*.

1483. A large number of sheep may be supplied by one person with sliced turnips by means of this slicer; but as the wheeled turnip-slicer is easier worked in the field for that purpose, this hand-lever slicer will be found a very handy machine for supplying sliced turnips to small numbers of sheep, as tups in winter, or ewes while lambing, in small fields or paddocks.

1484. *The Gridiron Horizontal Turnip-Slicer.*—The gridiron has also been applied in combination with a revolving crank motion; the gridiron reciprocating, and that in a horizontal position. This modification appears to have originated in Roxburghshire, and appears to possess some advantages, the chief of which is, that, as the roots lie directly *upon* the gridiron, they are more likely to be regularly sliced than in those machines where the roots lie only *against* the cutters, as in the common vertical disc machines. This machine is essentially a gridiron turnip-slicer, with a reciprocating motion, derived from a rotatory motion. The latter is produced by turning a winch-handle, the axle of which carries a fly-wheel and two crank levers, or, more properly, the crank of the winch serves for both; the throw of the handle being 15 inches, while that of the cranks is only 7 inches from the axis. A connecting-rod on each side of the machine connects the cranks with the gridiron-cutter, producing the reciprocating motion, which is in the horizontal direction; and to render the motion as easy as possible, the frame of the gridiron moves upon slide-rods.

1485. From the circumstance of the motion of the cutter being horizontal, and the turnips lying directly upon the gridiron, it can be easily constructed to cut both ways, that is, with the *out* as well as the *in* stroke; the gridiron for this purpose being furnished at both ends with the slicing-knife and the cross-cutting knives, as described in fig. 531.

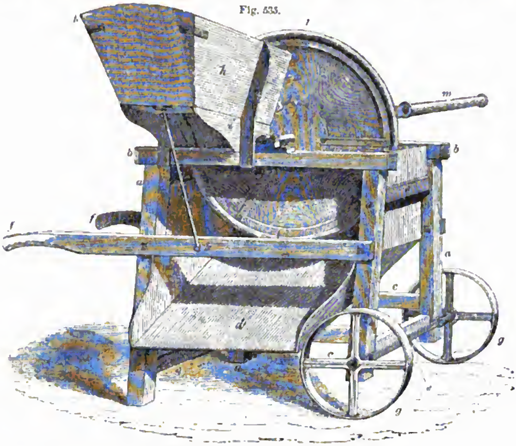
1486. The machinery here described is mounted on a wooden frame, 4 feet 6 inches long, 22 inches wide, and 34 inches high, and over the gridiron is placed a square hopper of wood or of sheet-iron, into which the turnips are thrown by an assistant, the machine being driven by a man. A bar of division is placed across in the middle of the hopper, serving as the point of resistance against which the turnips are pressed while the slice is being made; and as the turnips lie on the bars of the gridiron with their full weight, they will for the most part be in a position to secure a slice of uniform thickness being removed.

1487. A slight modification has been made on this machine by placing the gridiron on radius bars, making the cutter move in an arc of about 2 feet radius, instead of moving in a slide. The radius bars produce a lighter motion, but have no effect on the cutting principle.

1488. With a view to economy, the regular slicing of turnips is of more importance than many farmers are aware of. When a part of the turnip is cut into very thin, and even into fragments of slices, a very considerable proportion of it goes to waste. In choosing a turnip-*slicer*, therefore, one of its points should always be, that it should cut as far as possible to a uniform size, whatever that size may be, and not pass a large proportion of the sliced turnips in thin-edged slices, or thin and small fragments of slices.

1489. *Wheelbarrow Turnip-Slicer for Sheep.*—This machine has since its introduction undergone many modifications. From being made entirely of wood, it was then made entirely of iron; but iron being less convenient for moving about, has induced the more general introduction of a disc of cast-iron, carrying the cutters, mounted on a wooden frame, which is generally again mounted on wheels like a wheelbarrow. Fig. 535 is a perspective of this machine: the wooden frame, which is 36 inches long and 15 inches wide over the posts at top, but spreads a little wider below, is formed with four posts *a a a a*, one of which is only partially seen in the figure; they are 2¼ inches square, and stand about 32 inches in height. The posts are connected on the sides by top-rails *b b*, and two brace-rails *c c*, below, one of which serves to support the spout *d*, which discharges the sliced turnips. The sides of the frame thus formed are connected by cross-rails above and below, *e e e*, and is there furnished with the handle-bars *f f*, bolted to the posts, and projecting a convenient length beyond them at one end. The barrow-wheels *g g*, of 12 inches diameter, are fitted to an iron axle, which is bolted to the posts in front. The hopper *h* is fixed upon the top-rail by means of a cast-iron sole bolted upon the rail, and is further supported by a wooden bracket at each side, as seen at *i*, and by the iron stay *k*. The slicing-wheel *l* is a disc of cast-iron, carrying three sets of cutters. The disc is mounted on an axle passing through its

Fig. 535.

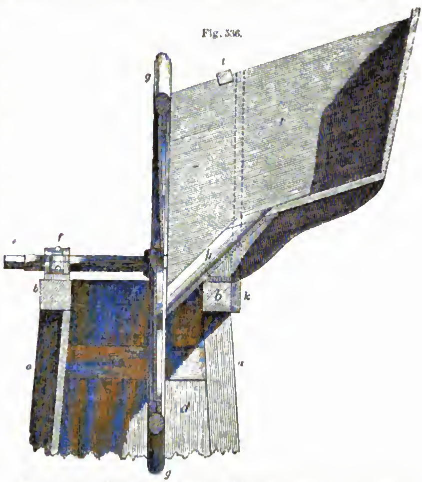


THE WHEELBARROW TURNIP-SLICER FOR SHEEP.

centre, where it is fixed, and which is supported on bearings placed on the top-rails, and, when worked, it is turned by the winch-handle *m*, fixed upon the axle.

1490. Fig. 536 is a section of part of this machine, cutting it through the hopper, and the disc, &c., to exhibit some of the parts more in detail. *a a* are parts of two of the posts, *b b* the top-rails, and *c* one of the end-rails of the frame, covered by the boarding *d* of the spout. *f* is one of the pillow-block bearings of the axle, the other being kept out of view by the hopper, and the winch-handle is applied at *e*. *g g* is the disc shown also in section. The sole of the hopper is represented at *h*; it has a flange between *h* and *b*, by which it is bolted to the top-rail *b*; and the sole itself

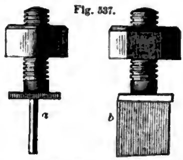
Fig. 536.



THE SECTION OF THE DISC AND HOPPER OF THE WHEELBARROW TURNIP-SLICER is a cylindrico-concave plate of 12 inches in length at the bottom of the concavity, 9 inches in breadth, and is placed at an angle of 45°. It is also furnished with a flange at each side, whereby the sides *i* of the hopper are attached to the sole. *k* is the foot of one of the brackets *i* referred to in fig. 535, rising in the position of the dotted lines, fig. 536, for supporting the hopper; and *t* is a light tie-bar, cut by the section, which is applied also to bind the sides of the hopper.

1491. The disc or wheel *g g*, fig. 536, is a plate of cast-iron, 32 inches in diameter and ¼ inch thick, encircled by a heavy ring of the same metal, to give it momentum when in action. The face of the disc is divided into three segmental compartments around a plain and central portion, which is 9 inches diameter. This central part lies in the general plane of the disc, while the segmental portions diverge from the plane in the direction of the circle, causing them to take the form of portions of three separate helical or spiral surfaces of 9 inches in breadth. Their divergence from the plane of the disc does not, however, exceed ¾ of an inch at the termination of a segment, or such other space as may be determined upon for the thickness of the slices. By this construction three slits are formed in the disc, passing obliquely through, one at the termination of each segment; and the steel slicing-knife, 12 inches in length and 1½ inch in breadth, is fixed by bolts, so as to form the entering edge of each segment, as seen in fig. 535; the flat face of the knife lying in the general plane of the disc. The terminal edge of each segment lies exactly behind the leading edge of the next, so that, when the slicing-knife is affixed to a leading edge, the edge of the knife covers 1½ inch of the length of the preceding segment. Into the border, which is thus covered by the slicing-knife, are placed from six to ten lancet shaft-cutters, their length being just equal to the width of the slit, and their distance apart proportioned to the number employed, or the breadth at which the turnips are required to be cross cut. The cross-cutters are formed as represented in fig. 537, where *a* is an edge, and *b* a side view of a cutter, with its tail and screw-nut, by which it is fixed into the disc.

Fig. 537.

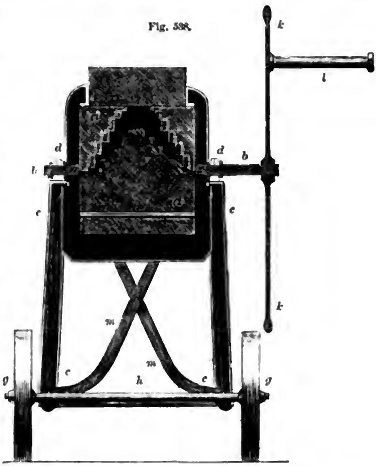


THE CROSS-CUTTERS OF THE DISC OF THE WHEELBARROW TURNIP-SLICER.

1492. It will be seen that the action of those compound cutters is very similar to that of the gridiron, the slicing and cross-cutting knives acting together, though the slicing-knife is here also about ½ inch in advance of the cross-cutters; and from the construction of the disc, and arrangement of the feeding-hoppers, the turnip is applied with great regularity and in close contact with the spiral surface of the segments of the disc. The slope of the sole-plate in the hoppers gives the turnip a constant tendency to keep in contact with the surface and the cutters, thereby securing regular and good performance by the machine.

1493. *Cylinder Turnip-Slicers.*—Turnip-slicers for sheep have been also constructed in a variety of forms, with the cutters set in the surface of a cylinder, and been in use for many years. In Roxburghshire it has been long and successfully employed in the locomotive principle, not driven by any machinery from the cart to which it is attached, but, being simply hooked to the cart, is drawn forward, and the machine being of some weight, and moving upon wheels of 3 feet or more in diameter, armed with spikes on their tires to prevent them sliding over the surface of the ground, and to give motion to the cutting cylinder, while a boy, sitting on the cart which contains the turnips that are to be cut, throws them into the hopper of the machine, from which they are dropped over the surface of the grass on which the sheep are feeding.

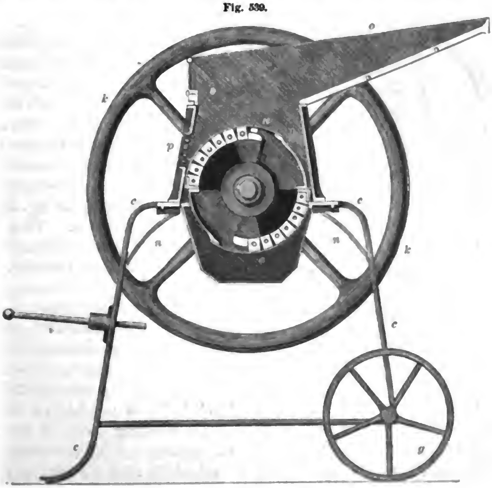
Fig. 538.



END ELEVATION OF CYLINDRICAL TURNIP-CUTTER—SCALE, ¾ INCH TO FOOT.

1494. *Gardner's Turnip-Cutter.* — A modification of the cylinder-slicer was patented in 1839 by Mr Gardner, Banbury: the principle of the patent lay in the form and arrangement of the cutters, which are set in three divisions upon the surface of the cylinder. The arrangement of the cutters is peculiar, and will be understood by the inspection of figs. 538 and 539. The cylinder on which the cutters are placed is 15 inches in diameter and 12 inches long. Its periphery is divided into three compartments, each forming a portion of a spiral, so that the commencement of one and the termination of the next leaves a slit across the periphery, corresponding in some degree with that described on the disc of the wheel turnip-cutter. The original cylindrical slicers had the slicing-knife extending in an unbroken edge across the surface of

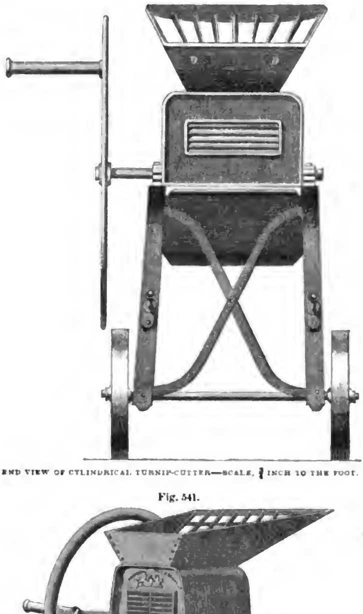
Fig. 539.



SIDE ELEVATION OF CYLINDRICAL TURNIP-CUTTER—SCALE, ¾ INCH TO THE FOOT.

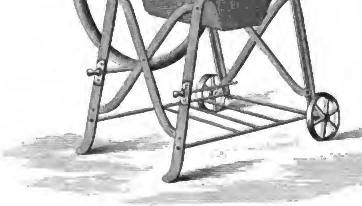
the cylinder, and the cross-cutters placed under and behind it. The improvement on which the patent was based may be described as cutting the slicing-knife into a number of sections, say of 1 inch each in length. The two extreme sections remain in the original position on the cylinder. The section next to that on each side is removed backward upon the surface of the cylinder—say $1\frac{1}{2}$ inch—and there fixed. The section on each side next to those is in like manner set back, and so on, till the whole are placed on the surface of the cylinder. By this arrangement the slicing-cutters form two converging lines, in echelon, and this is repeated three times on the periphery of the cylinder. The cross-cutters are formed by a part of the slicing-cutter being bent to a right angle with the cross-cutter.

Fig. 540.



END VIEW OF CYLINDRICAL TURNIP-CUTTER—SCALE, $\frac{3}{4}$ INCH TO THE FOOT.

Fig. 541.



CYLINDRICAL TURNIP-CUTTER IN PERSPECTIVE.

1495. Mr Samuelson, of Banbury, has introduced some improvements in Gardner's turnip-slicer, which we shall now describe. In fig. 538 is given an end elevation of a machine, in which the top hopper is removed, to show the cylinder; in fig. 539 a side elevation, with side of hopper and spout removed, to show the cylinder and cranked knives; in fig. 540 an end elevation. The whole of these are drawn to a scale of $\frac{3}{4}$ inch to a foot. Fig. 541 is a view in perspective.

1496. The cylinder *a a*, figs. 538, 539, $14\frac{1}{2}$ inches in diameter and $13\frac{1}{4}$ inches in length, is armed with thirty knives set in echelon behind each other round its periphery. Each knife is bent so as to form two sides of a rectangle, and has an opening corresponding to it in the cylinder, through which the cut piece is voided, passing into the interior of the cylinder as it revolves, and from the open ends of which it falls through a spout into a "skep" placed under the hopper. The cylinder is keyed on the shaft *b b*, fig. 538, 1¼ inch in diameter, and which revolves in bearings *d d*, fixed to the wrought-iron framing *c c c c*. The framing is supported by two wheels *g g*, 15 inches diameter and 2 inches broad in the periphery. These wheels are fixed on the shaft *h*, ⅝ of an inch diameter, revolving in bearings fixed to the lower part of the frame. When the machine is at work, it rests on these wheels, and the extremities of the two opposite supports of the frame act as feet. When it is required to be moved from place to place, the handles *i*, fig. 539, are brought into requisition for lifting the front part, the whole then resting on the two wheels *g g*. On the shaft *b b*, fig. 538, is keyed the fly-wheel *k k*, 37 inches in diameter, to an arm of which is fixed the handle *l*. The height from the ground-line to the top of the framing on which the bearings *d d* rest, is 2 feet 8 inches; to top of hopper, 4 feet 5 inches. The framing is strengthened by the flat wrought-iron stays *m m*, 1 inch broad, and by the round ⅝-inch iron stays *n n*, fig. 539. The upper part of the hopper *o o*, fig. 540, is grated, to allow the earth which adheres to the roots to fall away from them as they roll towards the cylinder. A vertical plate *p p*, figs. 539 and 540, against which they are pressed while being cut, is also grated, and tends to scrape the roots clean as they descend to the hopper.

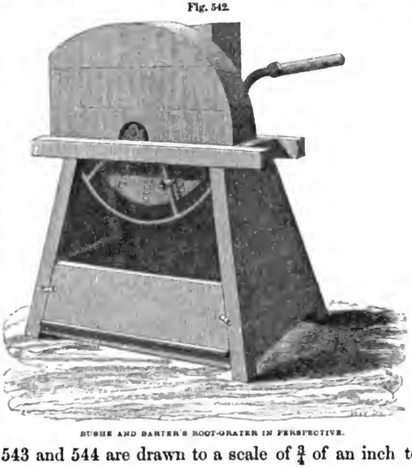
1497. When the machine is used to cut roots for cattle, the slices being required larger than when used for sheep, the cylinder is furnished with large slicing-knives, instead of the bent ones described in par. 1496.

1498. In Gardner's double-action turnip-cutter, manufactured by Mr Samuelson, there are both slicing and angular knives, so that large slices or small "fingers" may be cut by the same cylinder, according to the direction in which it is turned.

1499. The price of Samuelson's Gardner's turnip-cutter, as in the figures, to cut thirty pieces each revolution, ½ inch by ¾ inch for sheep only, with handles and wheels, is £5, 14s. 6d.; without these, £5, 2s. 6d. The price of the double-action cutter is, with handles and wheels, £6, 14s. 6d.; without, £6, 2s. 6d.

1500. *Bushe and Barter's Root-Grater.*—Machines to cut the turnips into very fine shreds have recently come much into requisition. Those are termed Root-graters, and a variety of patented forms are now before the public. We select for illustration that form known as Bushe and Barter's, as manufactured by Mr Samuelson. In fig. 542 is given a perspective view of this, in fig. 543 a front elevation, and in fig. 544 an end section. Figs. 543 and 544 are drawn to a scale of ¾ of an inch to the foot.

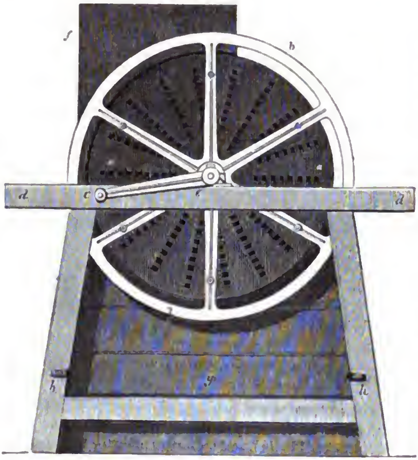
Fig. 542.



BUSHE AND BARTER'S ROOT-GRATER IN PERSPECTIVE.

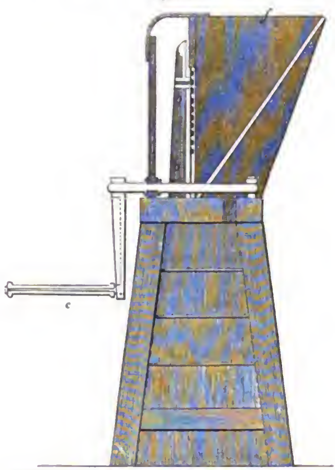
1501. A series of knives or cutters project from the disc *a a* in radial lines, as shown in fig. 543. The disc *a a* is 27½ inches in diameter, and is securely bolted to the arms of the wheel *b b*, 2 feet 9½ inches in diameter, keyed to a shaft ⅛ inch diameter, revolving in bearings *e*, fixed to the upper or cross beam *d d*, 4 feet long and 3 inches deep. The height from ground-line to the upper side of *d d* is 2 feet 5½ inches; from ground-line to top of hopper *f* 4 feet 4 inches. The receptacle in which the turnips lie, when exposed to the action of the cutters, is shown tapered as in fig. 544, the width at upper side being 14½ inches, and at bottom the thickness of the back-plate is ¾ of an inch. The handle *c* is 12 inches long. The roots, as they come in contact with the knives or cutters on the face of the disc *b b*, which is made to revolve by the handle *c*, are rapidly cut into thin shreds, which fall to the receptacle, *g*, fig. 543, formed in the lower part of the framing. While the machine is at work this receptacle is kept closed by a board, held in its place by two bolts *h h*.

Fig. 543.



FRONT ELEVATION OF ROOT-GRATER—SCALE, ¾ INCH TO THE FOOT.

Fig. 544.

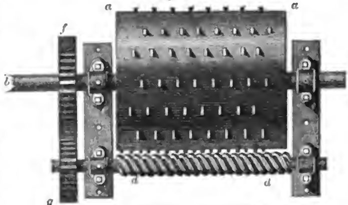


SIDE ELEVATION OF ROOT-GRATER—SCALE, ¾ INCH TO THE FOOT.

1502. Price of Bushe and Barter's root-grater is £3, 10s.

1503. *Bentall's Root-Pulper.* — In the class of machines known as "Root - pulpers," the roots are brought to a still finer state of subdivision than in the root-graters. Of the class of turnip-pulpers we select for illustration that invented and manufactured by Mr Bentall of Haybridge, Maldon, Essex. In this a barrel *a a*, fig. 545, 14½ inches long and 1 foot diameter, is fixed on a shaft *b c*, turned by the handle *i*, as shown in figs. 546 and 547, and revolving in bearings fixed in the upper frame of the machine *e e*, fig. 545. The barrel *a a* is provided with a series of knives, or rather hooked teeth, wedged into apertures or slots made in the periphery of the barrel, and which teeth are set in a helical form round the periphery. Parallel to this barrel, and close to it, so that the teeth of the barrel shall pass between the threads, an Archimedean screw *d d*, about 2 inches in diameter, revolves, motion being obtained from the shaft *b c* by the toothed wheels *f* and *g*. The pitch of this screw corresponds with the pitch of the helical line formed by the teeth in the barrel *a a*. As the barrel *a a* revolves, the teeth pass between the threads of the screw *d d*, and the combined action of the two (the tearing of the teeth and the squeezing of the worm-screw) very speedily reduces the roots to a good pulp. The iron teeth are wedged in by hardwood wedges, so that on any getting broken they can be easily taken out, and new ones substituted.

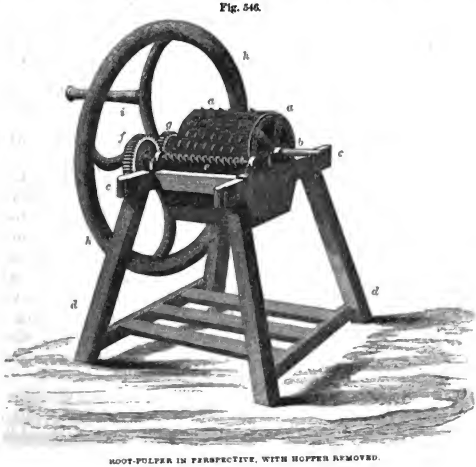
Fig. 545.



PLAN OF BENTALL'S ROOT-PULPER.

1504. In fig. 546 is given a perspective view of the machine, with the hopper removed, to show the connection of the different parts, and in fig. 547 a view as it appears when ready for work. In fig. 546 *a a* is the barrel, *b* the shaft

Fig. 546.

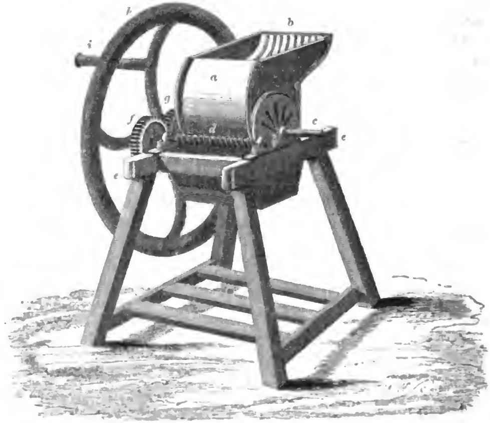


ROOT-PULPER IN PERSPECTIVE, WITH HOPPER REMOVED.

on which this is fitted, resting in bearings on the beam *c c*, supported by the standards *d d*; *e* the helical screw revolving in front of the barrel, *f* the spur-wheel keyed on to the shaft of the screw *e*, gearing with the pinion *g* on the shaft of the barrel *a a*.

1505. In fig. 547 *a* is the hopper, with grating *b*, *c* the shaft of the working barrel, *d* the helical screw, *e e* the beams supporting the bearings of the barrel

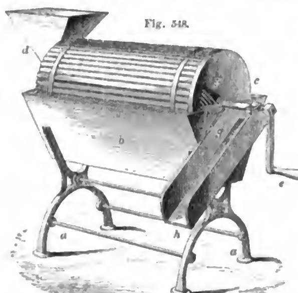
Fig. 547.



ROOT-PULPER IN PERSPECTIVE.

and screw; *f* the spur-wheel on shaft of screw *d*, gearing with the pinion *g* on shaft of barrel; *h* the fly-wheel, *i* the handle by which it is turned. Figs. 546 and 547 are drawn to a scale of ½ inch to the foot.

Fig. 548.



ROBINSON'S ROOT-WASHER IN PERSPECTIVE.

1506. The price of Bentall's root-pulper, capable of being worked by a man, is £5, 5s.; for power with 10-inch pulley, £6, 6s.

1507. *Robinson's Root-Washer.*—In fig. 548 we give a view in perspective of an excellent potato-washer, the invention of Mr Richard Robinson, late of Belfast. It consists of two cast-iron frames *a a*, connected together by means of three round malleable-iron rods. In the forks of these frames is inserted a wooden box or cistern *b*, wider at the top than at the bottom, to contain the water to wash the potatoes. The cylinder *c*, having a larger diameter at *c* than at the other end, is sparred with fillets of wood fastened on with iron hoops, at such distances as to prevent potatoes slipping through between them. The cylinder *c* is hung on the box *b* by means of an iron axle, which passes through both ends of the cylinder, and turns upon plumber-blocks, the nearest end being extended as far as to allow the trough *g* to be suspended between the box and the winch-handle *e*, which is supported on its extremity. The hopper *d* receives the potatoes, which pass over a grating in its inclined bottom, through which any earth or sand falls to the ground.

1508. The washer is used in this manner: Water is poured into the box *b* until it is nearly full. The potatoes are then put into the hopper *d* by means of a shovel or basket, and after passing over the grating find their way into the cylinder. On turning the winch-handle *e*, the cylinder revolves and takes the potatoes with it through the water; and as the potatoes find their way along its inclined bottom in the water, they are taken up by a twisted sparred inclined plane, which carries them to the opening *f* in its boarded end, *c*, to a level of the edge of the box, over which they run down the inclined plane of the slide *g*, which conveys them as far as *h*, where a tub, barrow, or basket, is placed on the ground to receive them in a thoroughly washed and clean state.

1509. The peculiar advantage of this machine is, that in turning the winch-handle *e* to the right, and keeping the hopper *d* supplied with dirty potatoes, it washes them, and throws them out clean in a continuous stream to the bottom of the slide *h*. On turning the winch-handle *e* to the left, the potatoes are retained within the cylinder until the washing is effected as completely as desired; and then, by turning it to the right, the potatoes are got quit of instantly.

1510. In machines heretofore in use, the washing process is stopped to fill and empty the cylinder, which must be raised out of the cistern for those purposes, and lowered again into it, by a tedious and laborious process.

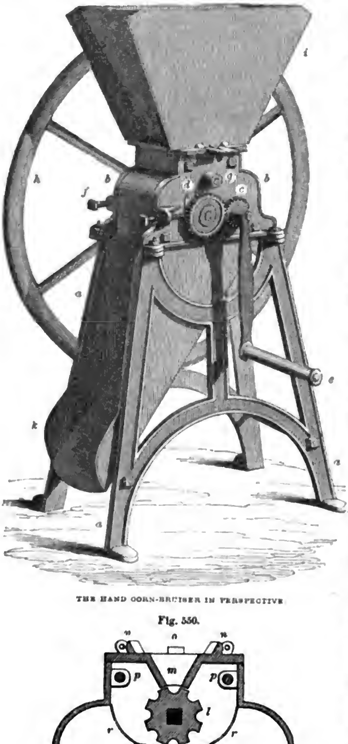
1511. The price of Robinson's root-washer is £3, 10s.

1512. SECTION SEVENTH.—*Corn-Bruisers—Bean-Mills.*

1513. *Corn-Bruisers.*—In following up an economical system of feeding, the bruising of all grain so applied, forms an important branch of the system, and, as might be expected, numerous are the varieties of machines applied to the purpose. These naturally arrange themselves under *three* distinct kinds: 1*st*, Machines which act on a principle that partakes of cutting and bruising, by means of grooved metal cylinders, and is applied to those chiefly driven by the hand; 2*d*, Machines adapted to bruise only by means of smooth cylinders: this is applied exclusively to those driven by steam, or other agency more powerful than the human hand; and, 3*d*, Breaking or grinding by the common grain millstones, and, of course, only worked by power.

1514. *The Hand Corn-Bruiser.*—That variety of the first division which we shall particularly notice is represented in perspective in fig. 549. It is constructed almost entirely of cast-iron, except the hopper and discharging-spout; but its frame or standard may with propriety be formed of hardwood, when circumstances render the adoption of that material desirable. In the figure, *a a a* is the framework, consisting of two separate sides, connected by two stretcher-bolts, the screw-nuts of which are only seen near to *a* and *a* below. A case *b b*, formed of cast-iron plates, is bolted upon the projecting ears at the top of the frame, and contains the bruising cylinders. The cylinders are 4 inches in diameter, and 6 inches in length, of cast-iron or of steel. They have an axle of malleable iron passing through them, having turned journals, which run in bearings formed on the cast-iron side-plates of the case, the bearings being accurately bored out to fit the journals. The spur-wheels *c* and *d* are fitted upon the axle of the cylinders, *c* having 14 teeth, and *d* 24 teeth. The cylinder corresponding to *d* is perfectly smooth, while that of *c* is grooved at a pitch of $\frac{1}{4}$ inch, and about $\frac{3}{32}$ inch deep, worked to sharp edges. The grooves lie obliquely on the face of the cylinder, being at an angle of 10° with the axis. The winch-handle *e* is attached to the axle of the roller *c*, whose bearings are permanent, while those of *d* are movable, being formed in separate plates, and fitted to slide to a small extent in a seat, for the adjustment of the cylinder to any desired grist. This adjustment is effected by means of the screws *f*, which act upon the sliding-plates of the bearings. *g* is one of the bearings of a feeding-roller, placed also within the case; it is turned by means of a toothed-wheel fitted upon the further end of its axle, and which is driven by another wheel of 24 teeth on the axle of the cylinder *d*. The fly-wheel *h* is fitted upon the axle of the cylinder *c*, and is $3\frac{1}{2}$ feet in diameter; *i* is the feeding-hopper, attached to the top of the case by two small hooks; and *k* is a wooden spout to convey the bruised grain from the case.

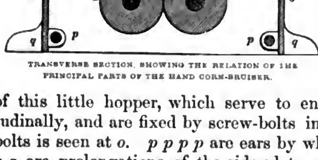
Fig. 549.



THE HAND CORN-BRUISER IN PERSPECTIVE.

1515. Fig. 550 is a section of the case, and the cylinders, detached from the frame. *b b* are the two ends of the case cut by the section; *c* is the grooved cylinder, *d* the smooth, and *l* is the feeding-roller —it is $3\frac{1}{2}$ inches diameter, and has cylindrical grooves formed on its surface to convey the grain; *o* is a cover of cast-iron fixed upon the top of the case; it has two round ears *n n*, with eye-holes, which serve to steady the hopper, and to which it is screwed by the hooks already mentioned. A hopper-shaped opening *m* is formed in the cover; it is 6 inches long, 3 inches wide at top, and 1 inch at bottom, and the edges fit closely upon the feeding-rollers. Two plate-iron sliders are fitted upon the surface of this little hopper, which serve to enlarge or contract the opening longitudinally, and are fixed by screw-bolts in each plate; the head of one of the bolts is seen at *o*. *p p p p* are ears by which the case is bolted together, and *q q* are prolongations of the side-plate of the case; *r r* are additional plates

Fig. 550.



TRANSVERSE SECTION, SHOWING THE RELATION OF THE PRINCIPAL PARTS OF THE HAND CORN-BRUISER.

of sheet-iron, to prevent the grain from being thrown over the cylinders unbruised.

1516. This is a very efficient machine for bruising either oats or beans, the adjustment of the plain cylinder to the requisite distance being easily accomplished by the adjusting screws; and to prevent the abrasion of the grooved cylinder, by coming in too close contact with the other, a stopper is applied on each side, to keep the slides from overreaching the proper safety distance. From the different velocities of the two cylinders, the grooved one being the fastest, it produces a cutting as well as a bruising action, which renders its effects on the grain more perfect than simple pressure. It can be worked by one man, who will bruise 4 bushels of oats in an hour.

1517. The price of the hand corn-bruiser is £6, 10s.

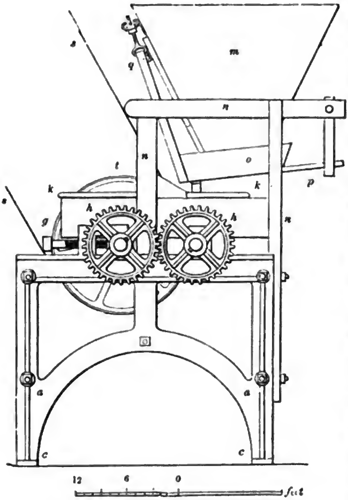
1518. Various other forms of this machine are in use, some with both cylinders grooved, others with only one grooved cylinder acting against a grooved plate; in this last state it is much used for bruising beans.

1519. *The Plain Wheel-edged Corn-bruiser.* — Amongst the varieties of the bruising machine of the second division (see par. 1513), we may just notice one that is found very efficient. It consists of two plain-edged wheels or pulleys, as they may be termed, usually about 6 inches broad on the rim or sole; the one ranges from 2½ feet to 4 feet in diameter, and its fellow only half the diameter of the larger. They require to be truly turned on the rim, and work in contact. The smaller one is always driven by the power, and the larger usually by contact with the smaller. The smaller wheel makes, according to its diameter, from 150 to 200 revolutions per minute. Where plain cylinders are employed for bruising, and their surfaces moving with equal velocity, the effect is to press each grain into a flat hard cake; but when one of the surfaces is left at liberty to move by simple contact, it is found that the effect is different, for the grain passes, bruised indeed, though not into a hard cake, but has apparently undergone a species of tearing, leaving it in an open and friable state. This machine, however, does not answer well for bruising beans, for here, again, they come through in the form of a flat cake. If beans, therefore, are used in an establishment where this bruiser is adopted, a separate one, on the principle of fig. 549, is required for the beans alone; that machine, though serviceable for a small establishment, being incapable, even with power, to produce the quantity in a reasonable time that would be required in a large one.

1520. *Plain Roller Corn-bruiser for Power.*—A very efficient corn-bruiser, adapted for power, is shown in figs. 551, 552, 553; fig. 551 being an elevation, fig. 552 a plan, and fig. 553 a section of the machine: the same letters apply to such corresponding parts as are seen in all the three figures.

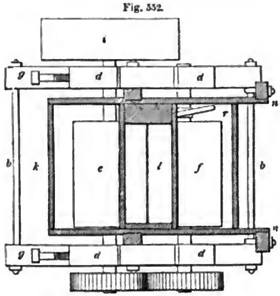
1521. In fig. 551, *a a* is one of the side-frames, of cast-iron, which are connected together by stretcher-bolts *b b*, and the frame so formed is bolted to a floor through the palms at *c c*. On the top bar of the frames there are two strong snugs *d d* cast, sufficient to resist the pressure of the rollers, and are formed also to receive the brass bushes in which the journals of the two rollers are made to run. The two rollers *e* and *f* are respectively 8 and 9½ inch diameter, and are 18 inches in length, fitted with malleable-iron shafts 1¾ inch diameter; the roller *f* runs in permanent bearings, but *e* has its bushes movable, for adjustment to the degree of bruising required, and this adjustment is effected by the adjusting screws *g g*. The shaft of each roller carries a wheel *h*, equal in diameter, which is 9 inches. The roller *e* has also upon its shaft the driving-pulley *i*, which by means of a belt *s s* from any shaft of a thrashing-machine, or other power having a proper velocity, puts the rollers in motion. The rollers are enclosed in a square wooden case *k k*, in the cover of which a narrow hopper-shaped opening *l* is formed to direct the grain between the rollers. A hopper *m* for receiving the grain is supported on the light wooden framework *n n*, which also supports the feeding-shoe *o*, jointed to the frame at *p*, and suspended by the straps *q*, which last is adjustable by a screw at *q* to regulate the quantity of feed. A smooth-edged oblique wheel *r*, fig. 552, is mounted on the shaft of the roller *f*, and by its oscillating revolutions, acting upon a forked arm which descends from the shoe, a vibratory motion is given to the latter, by which a regular and continued supply of the grain is delivered from the hopper to the rollers. After passing the rollers, the grain is received into a spout, which either delivers it on the same floor, or through a close spout in the floor below. The velocity of the rollers, which are driven by the belt *s s*, may be 250 revolutions per minute. The dimensions of the frame *a* are 30 inches in length and 24 inches in height, the width over all being also 24 inches.

Fig. 551.



THE ELEVATION OF THE POWER CORN-BRUISER.

Fig. 552.



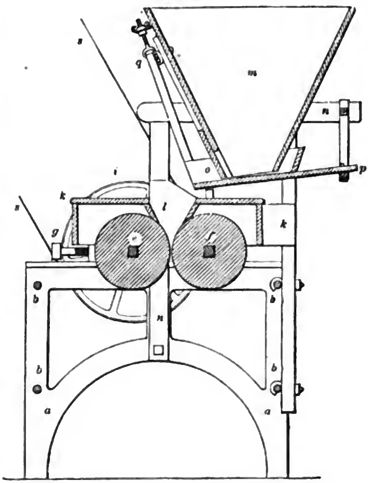
THE PLAN OF THE POWER CORN-BRUISER.

1522. The price of the plain roller corn-bruiser for power, as manufactured by A. and G. H. Slight, Edinburgh, is £10.

1523. *Turner's Roller-Mill.*—An exceedingly compact and well-constructed roller-mill is manufactured by Messrs E. R. & F. Turner, St Peter's Ironworks, Ipswich. Fig. 554 is a perspective view; fig. 555 a side elevation, and fig. 556 an end elevation. Figs. 555 and 556 are drawn to a scale of ½ inch to the foot.

1524. The framework is entirely of cast-iron, well braced and steadied; its height from the ground is 3 feet 2 inches, its length over all 5 feet 9 inches, its breadth at the foot is 2 feet 6 inches, and at top 13 inches. A large wheel *a a*, fig. 555, 4 feet in diameter and 6 inches broad in the rim, the periphery of which is turned with the greatest accuracy, revolves in bearings in the back part of the framing. This roller revolves in contact with a smaller roller *b*, $11\frac{3}{4}$ inches diameter, the periphery of which is also accurately turned. Motion is given to this roller by the roller *a a*, through the adhesion of the surfaces. Pressure is applied to the bearings of the small roller *b*, so as to bring it in contact with the large roller *a*, by means of the screw-wheel *c* acting through a coiled-up spring *d*; the diameter of the screw-wheel *c* is 9 inches. The spring *d* serves the double purpose of insuring a perfectly uniform pressure on the substances passing between the two rollers, and of allowing a hard substance, such as a nail or pebble, to pass through without injuring the surfaces of the rollers. To keep these surfaces clean, each roller is provided with a scraper, as *e* for the roller *b*, and *f* for *a*.

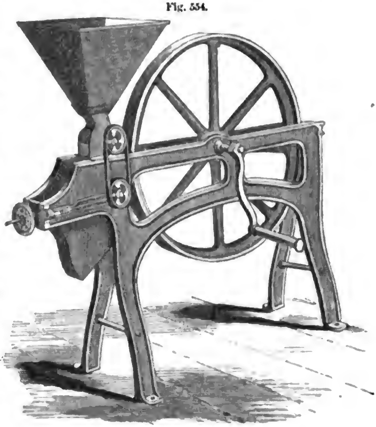
Fig. 553.



THE SECTION OF THE POWER CORN-BRUISER.

1525. A small feed-roller *g*, fig. 555, $2\frac{1}{2}$ inches diameter, runs at the back of the hopper, and serves to distribute the corn evenly between the rollers. The quantity of feed is regulated by a slide-door *h*, which is opened and closed by a rack and pinion. The pinion is fixed on a small spindle having a barrel-wheel *l* at one end for working the pinion. The roller *g* receives motion from the spindle of the small roller *b* through the medium of two pulleys *a* and *b*, fig. 556, 4 inches diameter, and a driving-belt; *a* being keyed on to the shaft of the roller *g*, fig. 555, and *b* to that of the roller *b*, fig. 555. The crushed grain is delivered to the shoot *c*, fig. 556. In fig. 556, *d* and *e* are the fast and loose pulleys for driving the mill by power; *f* is the wheel corresponding to the wheel *l*, fig. 555; *g* is the hopper, and *h* the screw-wheel corresponding to *c*, fig. 555.

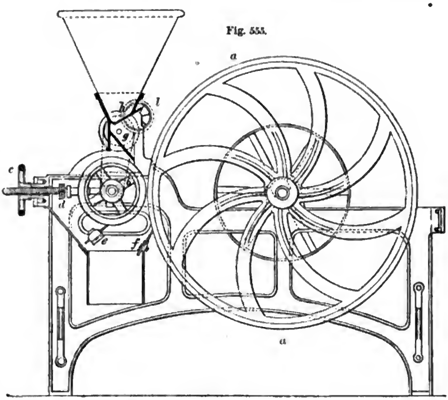
Fig. 554.



TURNER'S ROLLER-MILL IN PERSPECTIVE.

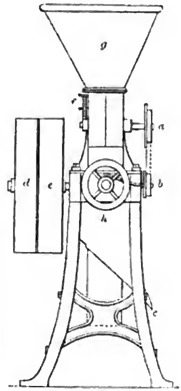
1526. The price of Turner's roller-mill, No. 2, to be worked by manual labour by the handle as in fig. 554, is £8; of No. 1, for power, £11, 11s.: pulley for extra power, 12s.; if turned and polished, 20s.

Fig. 555.



SIDE ELEVATION OF TURNER'S ROLLER-MILL.

Fig 556.

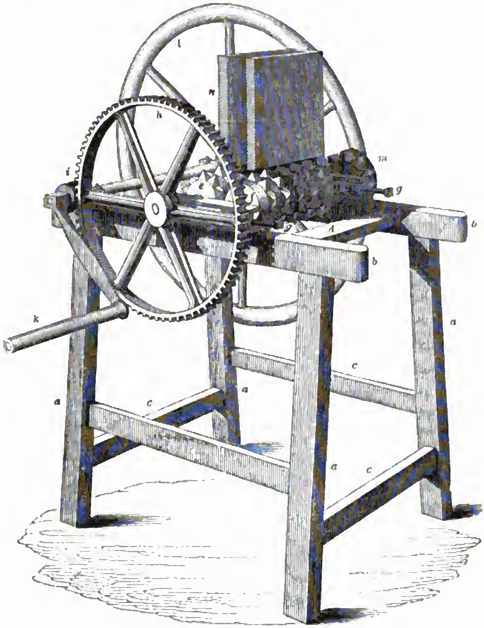


END ELEVATION OF TURNER'S ROLLER-MILL.

1527. *Oilcake-Breaker.*—Machines for preparing oilcake for more easy mastication by cattle or sheep are made in a variety of forms. One of those is similar in principle to that of the early bone-crushing machines—namely, a revolving axle armed with several series of teeth, which are so arranged as to pass in succession through the interstices of a line of strong teeth or prongs, against which the cake lies, and is reduced to fragments by the successive action of the revolving teeth. Of this form there are various modifications, all serving the same purpose with nearly equal success.

1528. A different form of the machine, and which is held to be superior in the principle of its construction, is here exhibited in fig. 557, which is a view of the machine in perspective, wherein *a a a a* are the four posts of a wooden frame, on which the machinery is supported. The frame is 39 inches in length and 20 inches in width over the posts at top, the height being 33 inches. *b b* are two top-rails, 34 inches in length, and the scantling of their timbers should not be less than 2¼ inches square. The posts are supported towards the bottom by the four stay-rails *c c c*; and the top-rails are held in position by cross-rails *d*, one only of which is seen in the figure. Of the machinery, the acting part consists of two rollers, studded all over with pyramidal knobs or teeth. These are arranged in zones upon each roller, and having a smooth space or zone between each of the knobbed zones; the knobs of the one roller corresponding to the smooth space in the other. The rollers *e* and *f* are constructed with an axle or shaft, that of *e* being 25 inches long, and of *f* 23 inches, and each 1¼ inch square. Journals are formed upon these shafts, to run in the bearings which are placed on the top-rails *b b*; *g g* are two pinching-screws, which serve to regulate the distance at which the rollers are to work, and, consequently, the degree of coarseness to which the cake is to be broken. The wheel *h*, of 20 inches diameter, is placed upon the shaft of the roller *e*, and the pinion *i*, of 3 inches diameter, with its shaft, and the winch-handle *k*, act upon the wheel *h*, giving a very considerable mechanical advantage to the power which is applied to the machine. The

Fig. 557.

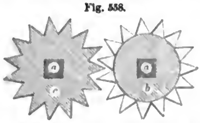


THE OILCAKE-BREAKER.

fly-wheel *l* is likewise placed upon the shaft of the pinion *i*, and is requisite in this machine to enable the power to overcome the unequal resistance of the work. On the farther end of the shaft of each of the rollers there is mounted a wheel of 4½ inches diameter, for the purpose of carrying both rollers at the same speed. These wheels, one of which is seen at *m*, are formed with long teeth, to admit of the roller *f* approaching to or receding from the other, which is stationary *in place*. A feeding-hopper *n* is placed over the line of division of the two rollers; it is 16½ inches long, 3 inches wide, and 14 inches deep. In forming the hopper, two upright pieces, 3 inches by 2 inches, are bolted to the inside of the top-rail, their position being between the shafts of the two rollers, and these form the ends of the hopper. They are then boarded on each side, which completes the machine. The hopper is here represented in section, the near portion of it being supposed entirely removed, in order to exhibit more distinctly the construction of the rollers.

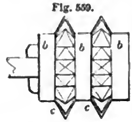
1529. Fig. 558 is a further illustration of the construction of the rollers, being a transverse section of the two: *a a* are the shafts, the shaded part *b* one of the plain discs which go to form the smooth zones on the body of the roller; it is 4 inches diameter and 1 inch thick: *c* is one of the knobbed discs, its body

Fig. 558.



THE TRANSVERSE SECTION OF THE ROLLERS.

Fig. 559.

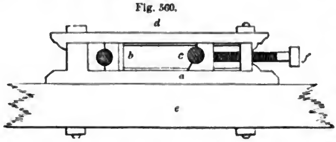


THE PLAN OF PART OF THE ROLLERS.

being of the same diameter and thickness as the former; but having the four-sided pyramidal knobs set around it, the diameter, measuring to the apex of the knobs, is extended to 6 inches. One roller for the machine here described requires five plain and six knobbed discs, beginning and ending with a knobbed disc. In the other the arrangement is reversed, bringing out the alternation of the plain and knobbed zones alluded to, par. 1528, as more distinctly represented in fig. 559, which is a plan of part of the rollers, *c c* being two of the knobbed discs, and *b b b* three of the plain.

1530. Fig. 560 represents one of the bearings or plummer-blocks for the journals of the rollers: *a* is the bed of the plummer-block, *b* and *c* the brass bushes, and *d* the cover. The bush *b*, which corresponds to the roller *e*, fig. 557, is always stationary, while *c*, which is acted upon by the screw *f*, is advanced towards or withdrawn from *b*, as the size to which the cake is to be broken may require. These plummer-blocks are bolted down to the top-rails *e* of the frame, to which also the separate bearings of the pinion-shaft are likewise bolted.

Fig. 560.



PART OF THE TOP-RAIL, WITH PLUMMER-BLOCK.

1531. The price of this oilcake-breaker is from £4 to £4, 10s.

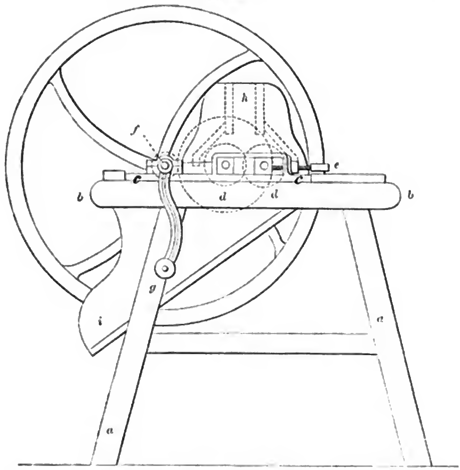
1532. It may be proper to remark here, that the machine now described is of a good medium size, and with a man to drive and a boy to feed in the cakes, it will break about half a ton in an hour. The amount of its performance can be augmented or diminished to only a small extent, for as its feed is necessarily confined to one cake at a time, the only change that can be made on its production must depend upon the celerity of its motions. Hence, it is one of those machines that cannot easily be adapted to *large* and to *small* establishments with any view to amelioration of form; for the almost only means of doing so must be by giving it a quicker or slower motion, which can only affect the expense of construction to a very small amount—so small as hardly to be appreciable.

1533. In addition to what is shown of this machine in fig. 557, the rollers are frequently covered with a movable wooden case, which gives a more tidy appearance to it; and, moreover, it is always desirable that the frame below should contain a *shoot* formed of light boarding, that will receive the broken cake from the rollers, and deliver it at one side of the machine into a basket or other utensil in which it can be removed to the feeding-stations.

1534. *Ransome and Sims' Oilcake-Breaker.*—A very compact form of oilcake-breaker is manufactured by Messrs Ransome and Sims, Ipswich, a side elevation of which is given in fig. 561, and a plan in 562, both drawn to a scale of ¾ of an inch to the foot: a perspective view in fig. 563, and a section, fig. 564.

1535. The framing *a a*, fig. 561, is 2 feet 8½ inches high, the standards or uprights being 3 inches by 2½ inches, mortised into side pieces *b b*, 2 feet 11¼ inches long, 3 inches deep, and 2½ inches thick. This framing supports the

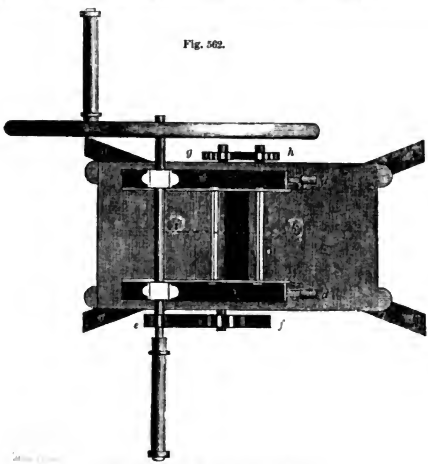
Fig. 561.



SIDE ELEVATION OF RANSOME AND SIMS' OILCAKE-BREAKER.

plates *c c*, carrying the bearings of the two rollers shown by the dotted circles *d d*; the distance between which is regulated by the two pinching-screws *d d* in fig. 562.

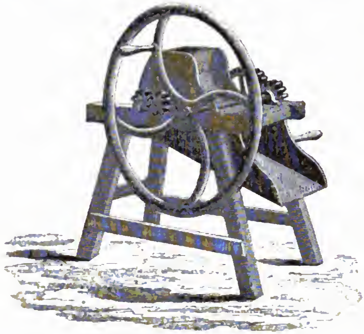
Fig. 562.



PLAN OF RANSOME AND SIMS' OILCAKE-BREAKER.

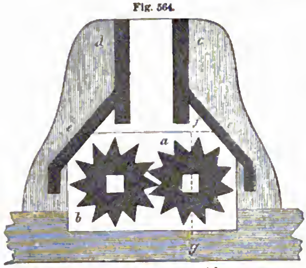
To the fly-wheel shaft *f*, fig. 561, worked by the handle *g*, the levers of which are 12 inches long from centre, a small pinion *e*, fig. 562, 3¼ inches diameter, is keyed; this engages with a spur-wheel *f*, 11 inches in diameter, keyed on the end of the spindle of one of the rollers. To the other extremity of this the pinion *g*, 4½ inches diameter, is keyed on, engaging with a similarly-sized pinion *h*, keyed on to the spindle of the other roller. The rollers are covered with a casing *h*, fig. 561, and the oilcake, after being crushed, passes off by the delivery-spout or shoot *i*.

Fig. 563.



RANSOME AND SIMS' OILCAKE-BREAKER IN PERSPECTIVE.

Fig. 564.



VERTICAL SECTION THROUGH LINE *i k* IN FIG. 562.

Fig. 565.

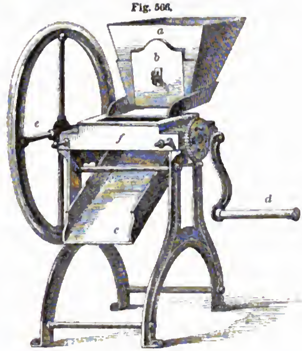
SECTION OF ONE OF THE CUTTERS.

1536. In fig. 564 is given a vertical section through the line *i k* in fig. 562, showing the form of the cutters *a* and *b*, fig. 564. These are 5 inches in diameter; the oilcake to be broken is passed between the pieces *c d*, 6 inches deep and 1 inch thick; the rollers are covered in at the sides by the wooden cap *e e* connected to the pieces *c d*. In fig. 565 is a section through *f g*, fig. 564, of one of the cutters, a series of which forming the rollers are fitted on square arbors or spindles *a*, 1¼ inch square.

1537. The price of this oilcake-breaker is £4, 10s.

1538. *Linseed-Bruisers.*—There are several efficient enough machines for bruising linseed into meal, though, from the oleaginous nature of the seed, the rollers are apt to clog up and get out of working order. A simple and cheap machine for the purpose is made by Mr A. Dean, Birmingham, which is driven by hand, and costs £6, 5s., and is represented by fig. 566, where *a* is the hop-

Fig. 566.



THE LINSEED-BRUISER

per for containing the seed; *f* the box containing the crushing-rollers; *c* the spout down which the meal descends; *d* the winch-handle which gives motion to the rollers; *e* the fly-wheel; and *b* the slide which regulates the feed to the rollers.

1539. Turner's roller-mill, as in fig. 554, is also an efficient linseed-bruiser.

1540. SECTION EIGHTH.—*Boiling and Steaming Apparatus.*

1541. *Cooking Food for Stock.*—The means employed for cooking food for horses and cattle are either boiling or steaming. In boiling, an open vessel is of course employed, in which the roots or other substances are placed, with a sufficient quantity of water. This method has been found inconvenient in many respects; and when the establishment is extensive, the vessel is required to be incommodiously large, and is withal not economical.

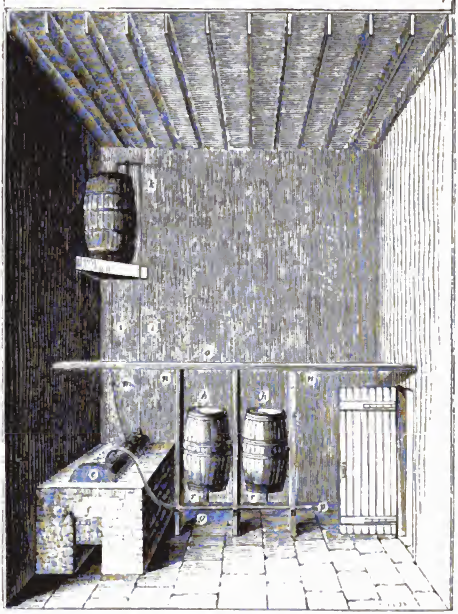
1542. *Open Boiler Steaming Apparatus.*—Steaming in a separate vessel has been adopted in preference to boiling, and has been followed in a variety of forms, but these may be ranked under two distinct kinds. The first is an *open vessel, a boiler*, generally of cast-iron, having a channel or groove of 1 inch wide and 2 inches deep formed round its brim. The vessel is placed over a furnace properly constructed, and is partly filled with water. The groove is also filled with water. A sheet-iron cylindrical pan, of 3 to 4 feet in depth, and of a diameter suited to pass into the groove of the water-vessel (which is generally about 3 feet diameter), is also provided. The pan has a perforated bottom, to admit steam freely from the lower vessel. It is also furnished with an iron bow, by which it can be suspended, and by which it can be conveniently tilted while suspended. This is the steaming-pan; and for the purpose of moving it to and from the boiler, a crane, mounted with wheel and pinion and a chain, completes the apparatus.

1543. To put this in operation, the pan is filled with the substances to be steamed, and covered over either with a deal cover or with old canvass bags. It is then placed upon the boiler by means of the crane, the fire being pretty strongly urged till the water in the boiler gives off its steam, which, passing up through the bottom of the pan, and acting upon the contents, produces in a few hours all the results of boiling. The water in the groove of the boiler serves as a sealing to prevent the escape of steam without passing through the pan. But notwithstanding this, it is evident that the steam can hardly ever reach the temperature of 212°; and hence this apparatus is always found to be very tardy in its effects. When the contents of the pan have been found sufficiently done, the whole is removed from the boiler by means of the crane, and tilted into a large trough to be thoroughly mixed, and from thence served out to the stock.

1544. A general complaint has been urged against this construction of apparatus, arising from the slowness of the process of cooking by it, and consequent expense of fuel. Boilers of the form here described are not well calculated to absorb the maximum of caloric that may be afforded by a given quantity of fuel, neither is the apparatus generally the best adaptation for the application of steam to the substances upon which the steam has to act. Such boilers, as already observed, can never produce steam of a higher temperature than 212°. If they did, the shallow water-luting, formed by the marginal groove, would be at once thrown out by the steam-pressure; for it is well known that the addition of 1° to the temperature of the steam increases its elasticity equal to the resistance of a column of water about 7 inches high. A groove, therefore, of 7 inches in depth would be required to resist the pressure, which would even then be only ¼ lb. of pressure on the square inch. Under such circumstances, the temperature in the steaming-pan will always be under 212°. Hence the tedious nature of the process by using this apparatus.

1545. *Closed Boiler Steaming Apparatus.*—A better apparatus than the above is represented in fig. 567. The principle of its construction is that of a *closed boiler*, in which the steam is produced under a small pressure of 3 to 4 lb. on the

Fig. 567.



THE CLOSED-BOILER STEAMING APPARATUS.

inch. It is then delivered through a pipe to one or more separate vessels containing the substances that are to be cooked; and these vessels are so arranged as to be readily engaged or disengaged with the conducting steam-pipe. The outline *a b c d* of fig. 567 represents a section of the steaming-house, with the apparatus in the order of arrangement, and of the extent that may be capable of supplying an establishment of from 10 to 16 horses. The boiler *e* is of a cylindrical form, 20 inches in diameter and 4 feet in length. It is set in brick-work *f*, over a furnace of 14 inches in width, with fire-grate and furnace-door. The brick building requires to be 6 feet 6 inches in length, 4 feet 6 inches in breadth, and the height about 3 feet 6 inches. The furnace is built with a circulating flue, passing first to the further end of the boiler, then turning to right or left according as the chimney may be situated, returns to the front of the boiler, and terminates in the chimney on the side opposite to the first turning. The flues should be not less in width at the upper part than one-fourth the diameter of the boiler; and their height will be about one-third the diameter. The steam-pipe is attached to the boiler at its crown, takes a swan-neck bend downwards to within 12 inches of the floor at *g*, and terminates at *p*; it is furnished with as many branch nozzles as there are intended to be steaming-vessels. The steam-pipe may be either of cast-iron or lead, and 2 inches diameter in the bore. The receptacles or steaming-vessels *h h* are usually casks of from 50 to 100 gallons contents. They are mounted with two iron gudgeons or pivots, placed a little above mid-height; they are besides furnished with a *false* bottom, supported about 3 inches above the true bottom; the false one being perforated with a plentiful number of holes, to pass the steam which is introduced between the two bottoms. The connection between the steam-pipe and the receptacle may be either by a stop-cock and coupling-screw—which is the most perfect connection—or it may be by the simple insertion of the one nozzle within the other, in the form of a spigot and faucet. If with spigot and faucet, the nozzle that leads from the steam-pipe is stopped with a wooden plug, when the steaming-vessel is disengaged. Besides the steam-pipe, the boiler is furnished with a pipe *i*, placed in connection with a cistern of water *k*, the pipe entering into it by the bottom, and its orifice closed by a valve opening upward, the lower extremity of the pipe passing within the boiler to within 3 inches of its bottom. A slender rod *l* passes also into the boiler through a small stuffing-box; and to its lower end, within the boiler, is appended a float, which rests upon the surface of the water within the boiler. The upper end of this rod is jointed to a small lever, which has its fulcrum supported on the edge of the cistern a little above *k*; the opposite end of the lever being jointed to a similar but shorter rod, rising from the valve in the bottom of the cistern. This forms the feeding apparatus of the boiler, and is so adjusted by weights, that when the water in the boiler is at a proper height, the float is buoyed up so as to shut the valve in the cistern, preventing any further supply of water to pass into the boiler, until, by evaporation, the surface of the water has fallen so far as to leave the float unsupported, to such extent as to form a counterpoise to the valve, which will then open, and admit water to descend into the boiler, until it has again elevated the float to that extent that will shut the valve in the cistern.

1546. By this arrangement, it will be perceived that the water in the boiler will be kept nearly at a uniform height; but to accomplish all this, the cistern must be placed at a certain fixed height above the water in the boiler, and this height is regulated by the laws which govern the expansive power of steam. This law, without going into its mathematical details at present, in so far as regards this point, may be stated in round numbers as follows: That the height of the surface of the water in the cistern must be raised above the surface of that in the boiler, 3 feet for every pound-weight of pressure that the steam will exert on a square inch of surface in the boiler. Thus, if it is estimated to work with steam of 1 lb. on the inch, the cistern must be raised 3 feet; if 2 inches, 6 feet; 3 inches, 9 feet; and so on. If the steam is by any chance raised higher than the height of the cistern provides for, the whole of the water in the boiler may be forced up through the pipe into the cistern, or until the lower orifice of the pipe, within the boiler, is exposed to the steam which will then also be ejected through the pipe, and the boiler may be left dry. Such an accident, however, cannot occur to the extent here described, if the feeding apparatus is in proper working order; and its occurrence to any extent is sufficiently guarded against by a safety-valve.

1547. The safety-valve of the steam-boiler is usually a conical metal valve, and always opening outward; it ought always to be of a diameter large in proportion to the size of boiler and steam-pipe, so as to insure the free egress of any rapid generation of steam. For a boiler of this size, par. 1545, it should be 2 inches in diameter on its under surface—that being the surface acted upon—this gives an area of fully 3 square inches; and if loaded directly, or without the intervention of a lever, for steam of a pressure of 1 lb. on the inch it will require 3 lb.; if 2 lb. on the inch, 6 lb.; if 3 lb. on the inch, 9 lb., and so on. With these adjustments, the steam, should it rise above the proposed pressure, will, instead of forcing the water through the feed-pipe, raise the safety-valve, and escape into the atmosphere until the pressure is reduced to the intended equilibrium.

1548. Another precautionary measure in the use of the steam-boiler is the gauge-cock, of which there are usually two, but sometimes one, a two-way cock; they are the common stop-cock, with a lengthened tail passing downward, the one having its tail terminating about 1½ inch below the proper water-level in the boiler, the other terminating 1½ inch above that level, which allows a range of 3 inches for the surface of the water to rise or fall. The first, or water-cock, then, when opened, will throw out water by the pressure of the steam upon its surface, until the surface has sunk 1½ inch below its *proper* level, when *steam* will be discharged, thus indicating the water in the boiler to be too low, and that measures should be taken to increase the supply. When the second or steam-cock is opened, it will always discharge steam alone, unless the water shall have risen so high as to come above its orifice, in which case the cock will discharge *water*, indicating a too large supply of water to the boiler, and that it should be reduced; for which purpose the feed-pipe *i* is provided with a stop-cock *m*, fig. 567, whereby the admission of water can be entirely prevented at the pleasure of the attendant.

1549. The foregoing description refers to a steaming apparatus of the best description, and implies that the water-cistern can be supplied either from a fountain-head, or that water can be pumped up to the cistern. But there may be cases where neither of these are easily attainable. Under such circumstances the feed-pipe may rise to the height of 4 or 4½ feet, and be surmounted by a funnel, and under it a stop-cock. In this case, also, a float with a wire stem, rising through a stuffing-box on the top of the boiler, must be employed; the stem may rise a few inches above the stuffing-box, in front of a graduated scale, having the zero in its middle point. When the water is at the proper height in the boiler, the top of the stem should point at zero, and any rise or fall in the water will be indicated accordingly by the position of the stem.

1550. To supply a boiler mounted after this fashion, the first thing to be attended to, before setting the fire, is to fill up the boiler, through the funnel, to the proper level, which will be indicated by the float pointing to zero; but it should be raised, in this case, 2 or 3 inches higher. In this stage the gauge-cocks are non-effective; but when the steam has been got up, they, as well as the float, must be consulted frequently; and should the water, by evaporation, fall so low as 3 inches below zero, a supply must be introduced through the funnel. To effect a supply in these circumstances, the steam must be allowed to fall rather low, and the funnel being filled, and the stop-cock opened, the water in the funnel will sink down through the tube, provided the steam be sufficiently low to admit its entrance, but the first portion of water that can be thus thrown in will go far to effect this, by sinking the temperature. The sinking of the temperature by the addition of a large quantity of cold water, is the objection to this mode of feeding; but this is obviated to some extent from the circumstance, that unless the steaming receptacles are large or numerous, the first charge of water will generally serve to cook the mess, when a fresh charge can be put in for the next.

1551. In using this steaming apparatus, it has been noticed, in par. 1545, that the casks are furnished with gudgeons, which play in the posts *n n*, fig. 567; these are kept in position by the collar-beam *o* to which they are attached, the casks being at liberty to be tilted upon these gudgeons. They are charged when in the upright position, and the connection being formed by the steam-pipe, they are covered at top with a close lid or a thick cloth, and the process of steaming goes on. When the substances are sufficiently cooked, the couplings *r r* are disengaged, the upper part of the cask is swung forward, and their contents discharged into a trough which is brought in front of them for that purpose.

1552. The connections with the steam-pipe are sometimes, for cheapness, formed by a *sliding tube* of copper or brass, about 4 inches in length, which, after the nozzle of the cask and that projecting from the steam-pipe are brought directly opposite to each other, is slid over the junction, and as a moderate degree of tightness only is requisite in such joints, a strip of sacking wrapped round the ends of the slider is found sufficient. On breaking the connection, and opening the exit nozzles, the steam will of course flow out, but this is checked by a wooden plug, or even a potato or slice of turnip, thrust into the orifice, may be sufficient. It is advisable, however, that a main stop-cock should be placed in the steam-pipe anywhere between the boiler and the first receptacle.

1553. The most perfect mode of connection between the steam-pipe and the receptacles is a *stop-cock and coupling-screw*. These should be of 1½ inch bore; they are more certain in their effect, and more convenient in their application, though attended with more expense in the first cost of the apparatus. In this case no main-cock is required. The extremity of the steam-pipe should, in all cases, be closed by a small stop-cock, for the purpose of draining off any water that may collect in the pipe from condensation. A precaution to the same effect is requisite, in the bottom of each cask, to draw off the water that condenses abundantly in it; or a few small perforations in the bottom will effect the purpose.

1554. It must be remarked, in regard to steaming, that in those establishments where grain of any kind is given in food in a cooked state, dry grain cannot be cooked, or at least dressed to softness in dry steam, the only effect produced being a species of parching; and if steam of high temperature is employed, the parching is increased nearly to carbonisation. If it is wished, therefore, to soften or even to boil grain by steam, it must be done by one of the two following methods: The grain must either be soaked in water for a few hours, and then exposed to the direct action of the steam in the receptacle; or it may be put into the receptacle with as much water as will cover it, and then, by attaching the receptacle to the steam-pipe by the coupling stop-cock, or in the absence of stop-cocks, by passing a bent leaden pipe from the steam-pipe, over the upper edge of the receptacle and descending again inside, to the space between the false and the true bottoms: the steam discharged thus, by either method, will shortly raise the temperature of the water to the boiling point, and produce the desired effect.*

1555. The time required to prepare food in this way varies considerably, according to the state of the apparatus, and the principle of its construction. With the apparatus just described, potatoes can be steamed in casks of from

* See *Quarterly Journal of Agriculture*, vol. vi. p. 33.

32 to 50 gallons contents, in thirty to fifty-four minutes. In casks extending to 80 gallons, an hour or more may be required.

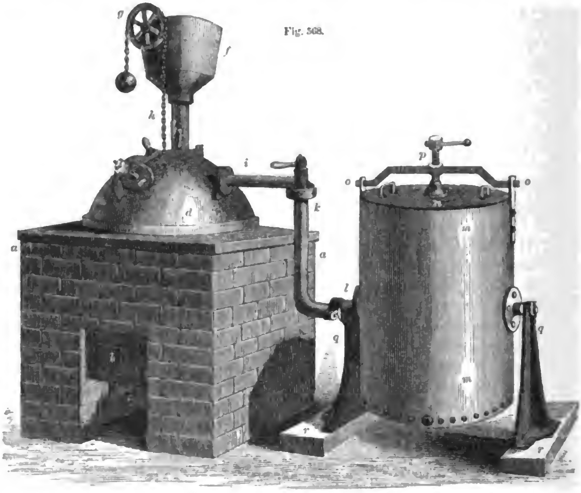
1556. Turnips require considerably longer time to become fully ready; especially if subjected to the process in thick masses, the time may be stated at double that of potatoes. When the apparatus is ill constructed, the time, in some cases, required to cook turnips, extends to five hours. And, with reference to the apparatus described in par. 1542, the time is seldom under five hours.

1557. The prices of steaming apparatus vary according to quality and extent; but, on an average, the open boiler and pan apparatus, including a power-crane, will range from £7 to £10; and of fig. 567, the price ranges from £8 to £16. The expense of building the furnace, and supplying mixing troughs, will add about £2, 10s. to each.

1558. In figs. 568 and 569, we give a perspective view of two exceedingly compact forms of steaming apparatus—fig. 568 being that of Messrs Richmond and Chandler, Salford, Manchester, an arrangement which has long had a high reputation—fig. 569 being that recently introduced by Messrs A. and W. Smith and Co., Glasgow.

1559. *Richmond and Chandler's Steaming Apparatus.*—In fig. 568 *a a* is the furnace of brick, *b* the furnace-door, *c* the ash-pit. The boiler *d* is capable of

Fig. 568.



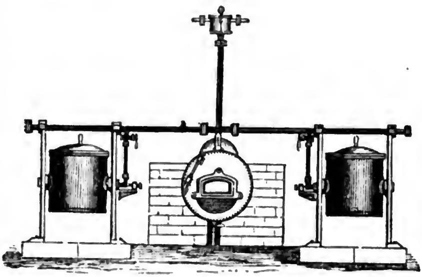
RICHMOND AND CHANDLER'S STEAMING APPARATUS IN PERSPECTIVE.

holding 30 gallons, and is supplied with self-acting feed-apparatus *f g h*, by which a due supply of water is maintained; *e* is the manhole door. The steam is led off by the pipe *i k l* to the mash-tub or cylinder *m m*. This is capable of holding 4 bushels, and is 30 inches long or deep, and 22 inches in diameter. It is swung on swivel-joints to the uprights *q q*, 22½ inches from the ground, bolted to the timbers or sole-plates *r r*. The supply of steam is regulated by the stop-cock on the pipe between i and k. The cover is kept on steam-tight by the pressure of the screw p passing through the bearers o o. The best wrought-iron plate is used in the construction of the boiler and receptacle; the feed-apparatus and boiler mountings are of cast-iron.

1560. The price of Richmond and Chandler's steaming apparatus is £6, 9s. If required, a second mash-tub can be placed at the other side of the boiler.

1561. *Smith & Co.'s Steaming Apparatus.*—In fig. 569, of Smith & Co.'s steaming apparatus, the boiler is on the Cornish or internal-flue principle. It is fitted with a furnace, two pans, and self-acting feed-valve and pipe, of which the illustration will convey a general idea to the reader.

Fig. 569.



SMITH AND CO.'S STEAMING APPARATUS IN ELEVATION.

1562. The price, with two pans to hold 85 gallons each, is £26, with flue-boiler; with plain boiler, £23. To hold 50 gallons each, with Cornish boiler, £18; with plain boiler, £10.

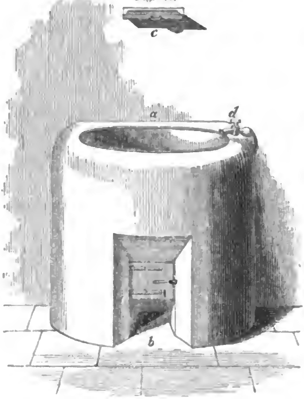
1563. Trouble and inconvenience are often felt in the use of a steaming apparatus of the most perfect construction, and far more of others of less ingenious arrangement; and the consequence is, that many are abandoning the steaming process altogether, and returning to the once contemned open boiler. It is quite possible that more fuel is required in the boiler than in the steaming apparatus to produce the same effects; but the boiler is so simple in its use, so ready at all times, so free from danger and accident, and so efficient in its results, that it may ultimately be the only apparatus in a farm that will be used to prepare food for either cattle or horses. We have had opportunities of witnessing the use of both apparatus in extensive farms where food is constantly prepared, and has been for many years past; and our conviction is now entirely in favour of the boiler. And now that potatoes, which are best cooked by steaming, cannot be depended on as a crop, and may, in future, bear a high price—and, on the contrary, as turnips, whose culture is extending every year, are best cooked by boiling—the boiler promises to become the more useful apparatus of the two.

1564. *The Common Boiler.*—Fig. 570 represents a common large boiler, fitted up in the best manner, where a is the cast-iron boiler, from $3\frac{1}{2}$ to 4 feet diameter across the top; b the furnace-grate for containing the fire, with its door; c the damper, in the flue for regulating the draught upon the fire; and d the stop-cock for supplying the boiler with water. The use of a boiler is so well known to country people that nothing need be said on it here.

1565. A sure method of preserving the front and top of the boiler from being broken, is to cover the first coat of plaster with stout coarse linen, and rub the second coat of plaster while moist through its texture, and to place a strong flagstone around the mouth of the boiler.

1566. But the boiler is not always properly built upon its seat in the furnace. It is furnished with two or three studs or ears, projecting from under the flange around its mouth, by which it may easily be suspended. A not unfrequent, but improper way of setting the boiler upon the furnace, is to cause the edge of its bottom to rest upon the building from both sides of the furnace-door to the back part of the building, where the flue is formed in connection with the chimney. The effect of this mode of setting is to cause the entire force of the fire in the furnace to strike against the bottom only of the boiler, and the greatest force will affect that part of the bottom which is nearest the furnace-door, the heat from whence must cook the entire contents of the boiler, and where at times the bottom must be so greatly heated—as when the contents of the boiler are removed immediately after they are sufficiently cooked, and cold water is poured into the boiler, in preparation for the cooking of another mess—that it is either cracked by the sudden cooling of the water, or is honeycombed by the fire, when the liquid in the boiler will ooze gradually through the corroded metal into the fire.

Fig. 570.

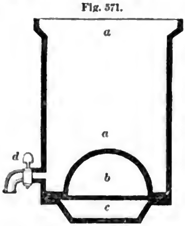


BOILER AND FURNACE.

1567. Now, the proper way of setting a boiler is this: When the building has proceeded so far as to have formed the ash-pit, and received the grate and dumb plate and furnace-door, to the height of the door, let a circular basin be built of the form of and a few inches larger than the boiler, to contain the boiler itself; and let it be so contracted, as it comes nearer to its height, as to suspend the entire boiler within the basin by its ears; and let a flue be built from behind, or at one side of the basin, as the case may be, into the chimney. The advantage of this mode of setting is, that the heat of the fire is not confined to one part of the boiler, but is diffused over the whole of its under surface; and though the heat may not be so great at any one part, it cooks the contents more equally, and preserves the boiler from overheating and injury.

1568. In any case a damper is a requisite part of a boiler and furnace, to regulate the draught through the fire, according to the state of the air. It is to be regretted that this regulator is little attended to after the first time it has been adjusted; and the consequence is, when the fire does not burn so briskly as desired, more coals or wood are put into the furnace; and when it burns too fiercely, it is regarded as a happy incident, instead of the draught of air being regulated by means of the damper, according to the circumstances of the case.

Fig. 571.



PORTABLE COMBINED FURNACE AND CALDRON.

1569. *Clarke & Co.'s Portable Combined Furnace and Caldron.*—In fig. 571 is given a section of a portable combined furnace and caldron, manufactured by Messrs Clarke and Co., Shakespeare Foundry, Wolverhampton. The boiler or caldron is at *a a*; *b* the furnace, with semicircular top, to expose as much of the heating surface to the material as possible; *c* the ash-pit; *d* the crane or stop-cock, by which to withdraw the contents of the boiler *a a*. In the form illustrated, the apparatus rests on an ash-pit, which forms the base, and is lifted from place to place by handles fixed to the boiler. To expedite removal, the apparatus may be mounted on wheels.

1570. Section Ninth.—*Dairy Apparatus.*

1571. *Churning.*—The process of churning, or agitating milk and cream for the production of butter, is performed in such a variety of machines, and in vessels so variously formed, each of which has its advocates, and, probably, with but little difference in the principal results, that it becomes a question of no small difficulty to answer which of these numerous forms is the best. That there will be slight differences, is at the same time sufficiently apparent; but these will arise more from the capacity of the vessel, as affecting temperature, than from peculiarity of structure, and probably also from other conditions affecting the chemical changes that take place during the process of churning. It will also be obvious, on a full consideration of the subject, that causes of difference will arise to some extent from the circumstances attending the more or less perfect nature of the agitation produced, as arising from the peculiar formation, and the motions, whether of the containing vessel or of the agitators.

1572. The peculiarities of the form of churns may be viewed under four distinct classes: 1. Those in which both the fluid and the containing vessel, with its agitators, are in rotative motion; 2. In which the containing vessel is at rest, and the agitators in rotative motion horizontally; 3. In which the containing vessel is at rest, and the agitators in rotative motion vertically; and 4. Wherein the containing vessel is at rest, and the agitator having a rectilineal vertical motion.

1573. In the class which has both the fluid and the containing vessel, with its agitators, in a rotative motion, is to be noticed those machines acting by their gyration on a centre, such as the old barrel-churn, wherein the contained fluid will have a tendency to acquire a motion of rotation approaching to that of the vessel; and if this rotation were continued always in the same direction, the process would be very much retarded from a deficiency of agitation: hence, in such machines, very frequent changes in the direction of the rotative motion is absolutely necessary to the completion of the process of making butter.

1574.—The second class embraces those in which the vessel is permanent, and an agitator of two or four arms revolves horizontally within it. If the vessel is cylindrical, the agitation will be imperfect, for the fluid will very soon acquire a motion *en masse*, and will be carried forward by the arms of the agitator, undergoing such agitation only as will arise from the central portion, acting by the centrifugal force, having always a tendency to fly towards the circumference of the revolving mass. This will no doubt ultimately, though slowly, produce the requisite effect, but it will be more speedily accomplished if the vessel is of a square form; for in that case the rotation of the mass will be interrupted at every angle, and eddies formed therein of such force as will not only cause disturbance of the fluid in these angles, but in doing so will produce corresponding counter-motions in the entire mass. From such causes, churns of this class and of the square form are found, especially on the large scale, to be very efficient, though, from the inconvenience of adopting manual power to a horizontal motion, it is seldom resorted to in the small scale.

1575. In the third class of machines, where the vessel is permanent, but having the agitators revolving in a vertical direction, the agitation is regular, and pervades at all times the entire mass of fluid; and in this respect there is little if any difference in effect, whether the bottom of the vessel be flat or cylindrical, nor is there any necessity for changing the direction of motion. We accordingly find that, whether on the large or small scale, churns of this class find favour in almost all localities.

1576. The fourth class of this useful machine is the upright or plunge churn. The vessel in this is also permanent, and its height, unlike all the others, is considerable, as compared with its breadth. As a matter of convenience, it is always made cylindrical, or rather slightly conical, which last property is given to it for the convenience of hooping, for in every other respect its tapering form is a defect. The plunger must necessarily always move vertically, without any rotative motion, and, when extended throughout the entire column of fluid, the agitation must be as complete as it is possible to attain.

1577. Plunge or vertical churns, therefore, are by many held as the most perfect for the production of butter, as well as for saving time in the operation; but there are objections to it as regards fitness for the adaptation of manual power. It is obvious to even a careless observer, that the human arm, if applied directly to the upright staff of this churn, the body being also upright, will be employing that power under the greatest possible disadvantages. The muscles of the arm, acting as they do in all cases under great natural disadvantages in respect of their leverage, will, in this peculiar position, be deprived of nearly all aid which the muscles of the trunk in many positions are calculated to give out to assist those of the arm; hence it is that the labour of working these churns by hand is found so oppressive, that the operator is unable to keep up a constant action; and the principle on which the churn is based is blamed for that delay in the operation, that ought rather to be attributed to the defect in the medium through which the power is applied. In proof of this, we find that when animal, or any of the inanimate powers, are applied to the vertical churn, it attains a character superior to all others, both as to time and production, and this character is sustained throughout some of the best dairy districts of Scotland.

1578. The advantages of applying hand-power through a proper medium are also observable in the case of this churn, when such power is applied through a winch-handle with a fly-wheel. Examples of this arrangement have been attended with the best effects, and with much ease, as compared with the direct application of the power to the plunger-rod.

1579. *The Barrel-Churn.*—In proceeding to the details of the churning machinery, the first class embraces those machines that act by their gyration round a centre, the fluid and the containing vessel revolving together, or partially so; of which the common barrel-churn may be taken as the type. The barrel, which is of capacity suited to the dairy, is sometimes provided only with a large square bunghole, secured by a clasped cover, by which it is charged and emptied; while in other cases, one of its ends is movable, and made tight by screwing it down on a packing of canvass cloth. In all cases, it is necessary that the interior of the barrel should be armed with three or more longitudinal ribs of wood standing as radii towards the centre, and perforated in various forms; these constitute the agitators of the churn. Each end of the barrel is furnished with an iron gudgeon or journal strongly fixed to it, and to one of them is applied the winch-handle by which the machine is turned; while it is supported on a wooden stand, having bearings for the two journals. More than one imperfection attends this construction of churn. From the circumstance of its rotatory motion, it will always have less or more of a tendency to carry the fluid round with the barrel and the agitators, more especially if a rapid velocity of rotation is given to it; and to counteract this tendency, it becomes necessary to reverse the motion at every few turns, which is of itself an inconvenience. There is, besides, the great inconvenience of getting access, either to remove the butter that may adhere to the agitators, or to cleanse the interior of the barrel. This is especially the case where there is no movable end; and even with this convenience for cleaning, the trouble of opening and closing the end is considerable. To those imperfections it is, no doubt, chiefly owing that this churn, once in high repute in East Lothian and Berwickshire, has gradually fallen into comparative neglect; and from these circumstances, it has been deemed unnecessary to give figures of this class of churn.

1580. *The Horizontal Churn.*—The machines to be here noticed under the second class are of a less varied character than any of the others, are seldom, if ever, used with hand-labour, but are generally worked by horse-power, and chiefly in town dairies, or in those around Edinburgh. From the comparatively small importance of this churn, it has been deemed unnecessary to give a figure of it; but its structure is so simple, that the following description will convey a tolerably correct knowledge of its construction to the mechanical reader. The horse-path, especially in towns, where space is valuable, seldom exceeds 16 feet; the horse-beam, with yoke, is fixed to an upright central shaft, which carries a spur-wheel placed at a height of about 3½ feet from the floor, the wheel being about 4 feet diameter. A churning-vessel, of dimensions varying with the extent of the dairy, is attached to the machine—and sometimes two vessels. For a dairy of 25 or 30 cows, where much of the produce is sold as sweet-milk, the vessel may be 2 feet 8 inches square and 2 feet 8 inches deep: it is placed securely on the floor at a proper distance from the central shaft, to suit the spur-wheel. A foot-step of metal is placed in the centre of the bottom, and a cross-head is attached to two uprights fixed on opposite sides of the vessel. The foot-step and cross-head serve as the two bearings for an upright spindle, which carries the four-armed agitator, and a pinion of 3½ inches diameter adapted to the spur-wheel. These parts, and a close cover for the vessel, complete the machine, which is therefore extremely simple; and in a dairy which is too extensive for manual power being applied effectually to churning, while want of space may preclude the adoption of more bulky machines, the one here described may be resorted to with advantage.

1581. *Whitworth and Eastwood's Compound-Action Churn.*—This churn is manufactured by the owners at Blackburn, Lancashire, and belongs to the second class. It has two agitators within the receptacle, which are moved by bevelled wheels of the same size, causing each agitator to have the same action and velocity. These wheels are mounted on a horizontal spindle, which is moved by a winch-handle, and when the churn is large, the action may be assisted by another winch-handle and a fly-wheel at the other end of the spindle. The spindle has bearings on two studs, connected by a bar that keeps the bevelled pinions on the top of the shafts of the agitators in their places, and the studs are secured on opposite sides of the churn with pinching-screws. The whole working gearing is easily removed, to allow the butter to be taken out of the churn, and the churn to be cleansed.

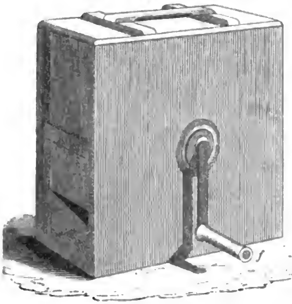
1582. This churn is equally adapted for the hand or for power, according to its capacity.

1583. Its price varies from £1, 13s. to £6, as it may churn from two to thirty gallons of milk or cream; 2s. per gallon extra being charged from thirty to forty gallons, and 1s. 6d. a gallon above forty gallons.

1584. *Churns* of the third class are much more numerous than the two former classes, and though in themselves not differing much in the essential points, they yet exhibit a variety of structure in their details. They are usually distinguished by the name of *box-churns*, though the class embraces not only the cubical and the oblong box, but also the cylinder or barrel, the distinctive character being an agitator revolving in the vertical direction within a stationary case of any form.

1585. *The Box Hand-Churn.*—To illustrate this class, we have selected, first, the common *box-hand churn*, in very general use. The present example, fig. 572, is 18 inches in length, 11 inches in width, and 20 inches in depth, inside measure. Birch or plane-tree are the best material for the purpose, and it requires to be very carefully joined so as to be water-tight. It is of very small moment whether the bottom is formed to the circle of the agitator, or remains flat, in as far as the production of butter is to be considered; but for the process of cleansing, the curved bottom will present some little advantages. A cover of the same material is fitted close in the top of the box, with convenient a handle.

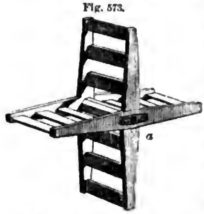
Fig. 572.



THE BOX HAND-CHURN.

1586. The agitator, fig. 573, is of the usual form; the dimensions of its parts are unimportant, except that they have sufficient strength, and present sufficient surface to produce the requisite degree of agitation in the fluid. The two pairs of arms are half lapped at the centre, and the cross-bars mortised into them; the dimensions in length and breadth being such as to allow it to move with freedom within the box. At the centre a perforation is made through the sides to admit the iron spindle, which, at this part, is a square bar, fitting neatly into socket-plates of iron let into the agitator on each side, as seen in the figure at *a*.

Fig. 573.



THE AGITATOR OF THE BOX-CHURN.

1587. The further end of the spindle projects about an inch beyond the agitator, and is rounded to form a journal, which has its bearing in a close brass plate-bush or socket, which is sunk into the side of the box, and fixed with screws. The outward end of the spindle is furnished with a conical journal, the smallest diameter of which is equal to the diagonal of the square part of the spindle, and is furnished with a raised collar or ruff; the conical journal lying in a thorough brass plate-bush, leaving the collar outside, but embraced by a cup of the bush, upon which a coupling-ring is screwed, covering the collar, and, pressing home the conical journal, preventing thus the spindle from being withdrawn until the coupling-ring is removed. The spindle extends beyond the collar about 2½ inches, and is here formed into a square stud, upon which the eye of the winch-handle *f*, fig. 572, is shipped when in work.

1588. In rigging this apparatus, the agitator is placed within the box, and the spindle is pushed through the outer bush and the agitator, until its two journals rest in the bushes; the coupling-ring is then screwed on to the outer bush, until the spindle with the agitator just turns round with freedom in the conical bush. To prevent the ring from turning round by the motion of the spindle, a smooth ring or washer of steel may be interposed between the collar and the brass ring.

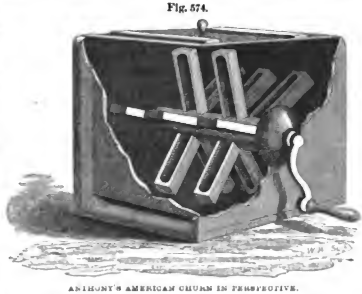
1589. Various other modes of securing the spindle are employed, but in all, the object is to prevent leakage at the bush.

1590. To prevent taint from galvanic influence, also, it is not uncommon to apply bone or other animal substance for the bushes.

1591. *The Box-Churn with Power.*—Churns of this kind are made of all sizes, without any change in the principle of their construction. They are applied to all kinds of power, and the capacity is proportioned to the extent of the dairy; but the *entire* capacity of the churn must be in general about double the quantity in gallons of the fluid intended to be acted upon. In operating with the box-churn, it may be filled to the height of the spindle, or, if that member is well fitted, the milk may rise considerably above it, though in general practice it rises but little above. To adapt the churn to power, it is only necessary to put a pulley for a strap, or a chain, upon the end of the spindle, in place of the handle; or the spindle may be attached to another shaft, having the proper velocity, by means of a slip-coupling. The velocity of the agitator must depend upon the size of the churn: one of 24 inches diameter may make 60 revolutions per minute on the average, but may be higher or lower in the different stages of the process.

1592. *Anthony's American Washer-Churn.*—In fig. 574 we give a perspective view of Anthony's American washer-churn (agents, Messrs Burgess and Key), with a part of two sides removed to show the arrangement of the interior. This churn has a high reputation as a quick butter-maker. The dimensions of the 14-lb. churn are—width 12½ inches, length 19 inches, extreme depth in the centre 12½ inches; depth to the top of the bevel at the sides 9 inches; length of crank of handle 8 inches.

Fig. 574.



ANTHONY'S AMERICAN CHURN IN PERSPECTIVE.

1593. The price of this size of the American washer-churn is £2, 15s.

1594. *The Plunger-Churn.*—In the fourth class of our subdivision there is only to be considered the *plunger-churn;* for in this class there is no variety, except as to the dimensions. The means of working the plunger, and the different media through which the power is applied, whether of man or of animals, are of a character much more varied than in all the others put together; and all these varieties seem to have been suggested, with a view to overcome the very unfavourable position in which a man applies his force directly to the plunger-rod of this churn. Amongst these varieties of construction in the mechanical media through which power, of whatever kind, may be applied, we find all possible varieties of the lever and its combinations, the loaded pendulum, with combinations of the lever of rack-gearing, crank and lever, and crank with connecting-rods; but it would be profitless to enumerate all the forms that have been devised for the improvement of this particular kind, and much more so to attempt to describe them. We will, therefore, rest satisfied with *one* that has long been in extensive use, and is equally well adapted to the hand, or to *power* of any kind.

1595. The upright or *plunge churning-vessel* is always a piece of cooper-work, varying in capacity, according to the extent of the dairy in which it is to be employed, from 10 to 130 gallons. It is illustrated in fig. 575. It is built slightly tapering upward for the convenience of being tightly hooped, having a strong bottom and a movable cover, which may be fastened down with an iron clasp-hoop; a perforation is formed in the centre of the cover for the passage of the churn-staff or plunger-rod, and this is surrounded by a wooden cup, to prevent the lashing over of the fluid in the act of churning.

Fig. 575.

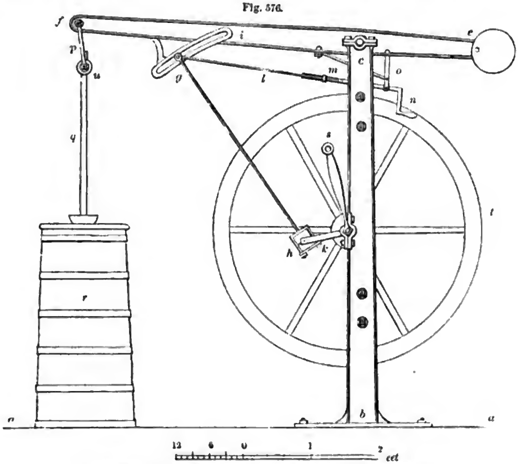
PLUNGER-CHURN.

1596. The plunger or agitator, which is attached to the bottom of the plunger-rod, is a circular reticulated frame of wood; the meshes may be from 1½ inch to 2 inches square, and the bars forming the reticulation about ⅝ inch thick and 1½ inch deep, the whole embraced by a wooden hoop, whose diameter will just enter the top of the churn. The structure of the plunger is by no means important, the only essential point being, that it shall not present too much resistance to the passage of the fluid through its interstices, nor too little, to give it a too easy passage, which might render the agitation so slight as to be ineffectual: a good medium is to make the horizontal area of all the interstices 1.5 times the area of the solid parts, and this rule will apply to the agitators of all churns. Such is the simple construction of this churning-vessel, which is capable of adaptation to any kind of power, and to any extent of dairy.

1597. *Plunger-Churn with Hand-power Machine.*—In figs. 576, 577, we illustrate a form extensively used in Lanarkshire and the neighbouring counties, where they are usually worked by one horse. Fig. 576 is a side elevation of the churn, and the mechanism required within the churn-room of the dairy. It is here represented as being for hand-power; but the arrangements of the machine, so far as here exhibited, are the same whether for man or horse. Fig. 577 is a back view of the same, and the same letters apply to the corresponding parts in each figure.

1598. The floor-line of the churning-room is represented by the line *a a*, and *b c* is an upright frame of cast-iron, which is bolted to the floor. The frame consists of two cheeks, which are bolted together on the flanged bars *d d d*; it is 5 feet 9 inches high, and 16 inches wide. The reciprocating cast-iron lever *e f* is supported by its fulcra on the top of the frame, by means of a centre-shaft passing through the lever. The length from the fulcrum to the head *f* is 4 feet 2 inches, and from the same point backward to the extremity is 2 feet 3 inches: a counterpoise is here placed upon the lever to bring it nearly to an equilibrium. The connecting-rod *g h* is jointed upon a bolt that is fitted to move along the oblique groove *g i* formed in the lever, and the crank *k* is formed on a shaft that turns in bearings in the upright frame; its throw is

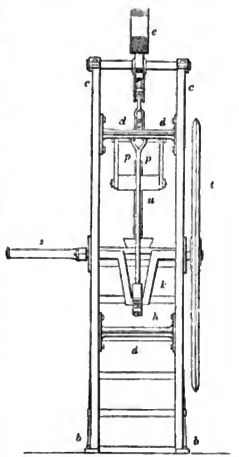
Fig. 576.



SIDE ELEVATION OF THE PLUNGER-CHURN WITH HAND-POWER MACHINE

8 inches, less or more, proportioned to the height of the churning vessel, and the foot *h* of the connecting-rod is fitted to the crank-pin. *l* is a light sheers of malleable iron, whose forked ends embrace the head of the connecting-rod, which is also forked at the head, and the pin of the groove passes through all three. The adjusting-screw *m*, with its winch-handle *n*, is supported in a swivel socket in the bracket *o*; while its screwed end *m* works in the bend of the sheers *l*, which is screwed as a nut to receive it, for the purpose of shortening or lengthening the distance *m g*, and so changing the position of the head of the connecting-rod. The head *f* of the lever is mounted with a pair of side-links *p p*, jointed on a cross-head in *f*; the links are again jointed on a wooden cross-head *u*, into which the head of the plunger-rod *q* is inserted, and fixed by a pin or key; these side-links, jointed as they are at top and bottom, produce a very imperfect parallel motion, but sufficient to answer the rise and fall of the plunger-rod. The handle *s* is fixed on one end of the crank-shaft, and on the other is placed the fly-wheel *t*, to equalise the motion of the lever, and compensate the inequality of the resistance to the plunger in its ascent and descent. The

Fig. 577.



BACK VIEW OF THE PLUNGER-CHURN WITH HAND-POWER MACHINE churning-vessel *r* is 3 feet high, with an average diameter of 15 inches, and capacity about 23 gallons.

1599. In extensive dairies, it is common to have two churning-vessels attached to the machine, in which case the wooden cross-head *u* is elongated so as to receive the head of the plunger-rods of both vessels, the vessels standing side by side during the operation.

1600. When this machine is in operation, the revolutions of the crank produce a reciprocating action in the connecting-rod, which is communicated to the lever, and thence to the plungers; and it will be seen that, by moving the head *g* of the connecting-rod in the oblique groove of the lever, the strokes or reciprocations of the plunger will be long or short, as the joint *g* is moved upward or downward in the groove *g i*. It is found from experience, that there are advantages to the process derivable from this; hence, at the commencement of the operation, the head of the rod *g h* is kept at the lower extremity of the slit, producing the shortest stroke; as the fluid becomes heated, and from the consequent effervescence its bulk is increased, the stroke is gradually lengthened by turning the handle *n* of the screw, and by thus shortening the distance *g m*, the pin at *g* is brought to the head of the slit, producing a stroke of the greatest length; and when the effervescence ceases and the butter has begun to form, this state is reversed, the stroke is gradually shortened, till the process is finished with the shortest stroke.

1601. The application of power to this machine is easy and commodious. It may be effected by a pulley placed on the crank-shaft instead of the handle *s*, and so driving with a strap or chain; or it may be driven by a spur-wheel placed on the same point, calculated to the speed that may be afforded by the power, whether horse, water, or steam.

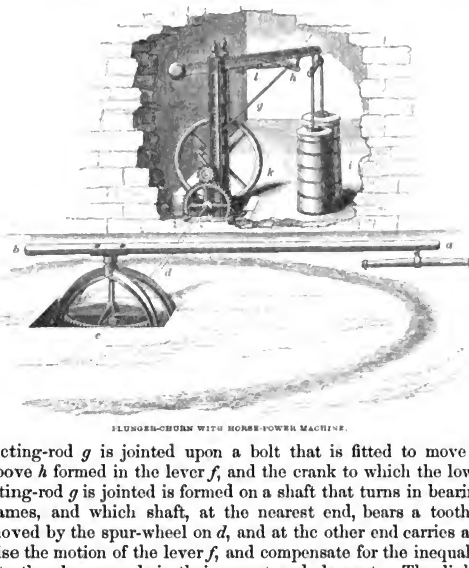
1602. The usual rate of the plunger in these churns is about 50 to 55 double strokes per minute, subject to the usual variation that is required in the different stages of the process.

1603. The price of the hand-machine, as in fig. 576, is from £6 to £8; and when completed with horse-wheel and gearing, it is from £15 to £18.

1604. *Plunger-Churn with Horse-Power Machine.*—Fig. 578 illustrates the arrangement of the mechanism when horse-power is used.

1605. It gives a view in perspective of the horse-course and churning-room in relation to one another, and which is the more clearly shown by removing a portion of the wall that separates them. The power in this case is that of the horse, which seems necessary to be adopted where no water is available for the purpose, and where one or two churns only are to be driven; for a steam-engine, which would only be employed in such a case as this every other day for three or four hours, and be restricted to give out only one-horse power, would be too expensive an erection for so diminutive an application of power. Where a thrashing-machine is used, and chaff-cutters and a bruising-machine employed along with the churn, a steam-engine would be an economical source of power. Taking the horse-power in this instance as the best in the absence of water, *a b* is the lever in the horse-course, to which the horse is yoked by the swing-tree at *a*; *c* is the pit containing the bevelled wheel, and the four arms of the frame which support the upright axle to which the lever *a b* is attached. This wheel moves horizontally, and acts upon a bevelled pinion fixed on the nearest end of the lying shaft *d*, which, being represented in dotted lines, must be supposed to work underground; and its further end is attached to and moves a spur-wheel, situated in the churning-room, close to the working gear of the churns. On the bottom of a corresponding pit in the churning-room rise two parallel frames of cast-iron, connected together at the top, and kept asunder by a flanged iron-bar. The reciprocating cast-iron lever *f* is supported by its fulcra near the top of the frame, by means of a centre shaft passing through the frames. A counterpoise is placed at the short end of the lever *f*, to bring it nearly to an equilibrium.

Fig. 578.



PLUNGER-CHURN WITH HORSE-POWER MACHINE.

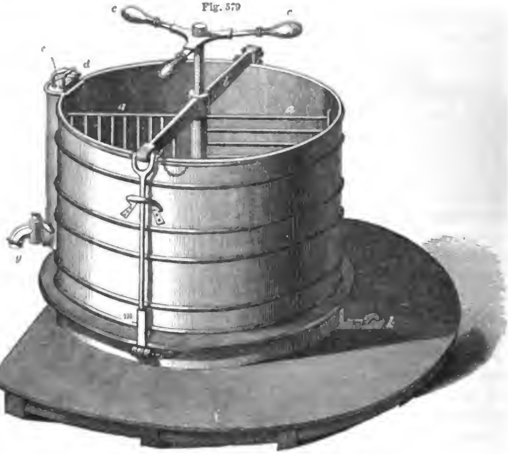
The connecting-rod *g* is jointed upon a bolt that is fitted to move along the oblique groove *h* formed in the lever *f*, and the crank to which the lower end of the connecting-rod *g* is jointed is formed on a shaft that turns in bearings in the upright frames, and which shaft, at the nearest end, bears a toothed pinion which is moved by the spur-wheel on *d*, and at the other end carries a fly-wheel *k*, to equalise the motion of the lever *f*, and compensate for the inequality of the resistance to the plunger-rods in their ascent and descent. The light sheers *l* embrace the connecting-rod within its forked end at *h*, and at the other end is connected with an adjusting-screw for the purpose of lengthening and shortening the distance *l h*, and so changing the position of the head of the connecting-rod. The head *f* of the lever is mounted with a pair of side-links, jointed at one end to the cross-head at *f*, and at the other with the wooden cross-head into which the ends of the plunger-rods of the churns *i* are placed side by side. These side-links, jointed as they are at top and bottom, produce an imperfect parallel motion, but sufficient to answer the rise and fall of the plunger-rods.

1606. *Oscillating Churn.*—Besides the four established classes of churns now described, there are a few other anomalous cases which have of late years been brought forward by inventors; and though they ultimately may be found to possess merit, they cannot yet be received as of established character. The machines to which we here allude may be named "oscillating churns." They possess no distinct agitator, but produce their effects by a species of oscillation produced in the fluid. Amongst these may be mentioned a vessel of an oblong form, placed upon skids, curved in a manner that, when the vessel is touched with even a gentle force, it will assume a motion resembling the well-known swing of a child's cradle, which will thereby produce a constant succession of irregular oscillatory motions in the contained fluid, which will produce the effect of churning. Mr Paterson of Beverley patented a churn on this rocking or oscillating principle. It consists of a rectangular box, supported on two levers, one at each end, these being jointed to the framing and under side of the box. As the box is pushed and pulled to and fro by the hand, it oscillates or vibrates from right to left, and its contents are alternately dashed in contrary directions.

1607. *Keevil's Cheese-making Apparatus.*—We now describe and illustrate a very important invention, namely, Keevil's cheese-making apparatus for cutting, filtering, and pressing curd. If this apparatus fulfils the high character which its success up to the present date would seem to justify, its introduction will be a great boon to dairy farmers in facilitating what is now, and has long been, most laborious processes. It is manufactured by Messrs Griffiths, of Bradford Street, Birmingham.

1608. The apparatus consists of a circular vessel of zinc, or, if preferred, of brass, placed on a wooden platform *i*, fig. 579. The upper part of this

Fig. 579



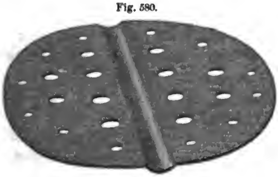
KEEVIL'S CHEESE-MAKING APPARATUS IN PERSPECTIVE

platform is fitted to the bottom of the circular vessel, giving it a solid bearing on the wood, and so enabling it to sustain the great pressure produced by the action of the screw hereafter described. It also serves as a frame to fasten down the beam *b* while the screw is in use, by means of the connecting-rods at each side, one of which is shown at *m*. The platform is fixed on iron rockers, so that the vessel may be tilted forward to allow the whey to draw more freely to the tap *g*; when not required to be tilted, it is kept level by the bolt *k*. Across the vessel, a beam *b* is fixed, the centre of which carries a bearing for a vertical axis or spindle. On this spindle knives *a a* are hung, one set of which is placed horizontally, the other vertically. A handle *c c* is used to give motion to the knives.

1609. At one side of the circular tub or vessel, a subsidiary receptacle of a semicircular form, as shown at *e*, is provided; this is of the same depth and height as the main vessel, and communicates with it by means of a filter-plate, *d*. This semicircular case is provided with a plug, furnished with a handle *e*; a stop-cock *g* is also provided at the foot of the vessel. So long as the plug *e* remains in the semicircular vessel, the whey from the main vessel is prevented passing through the filter-plate *d* to the stop-cock *g*: on removing it, however, by means of the handle, the whey flows through the filter-plate *d* into the semicircular vessel, from whence it may be withdrawn at pleasure by the stop-cock *g*.

1610. As soon as the curd is set, the handle *c* is turned slowly round, causing the knives on the spindle to cut the curd very gently; when the curd is cut sufficiently small, the knives are removed and the curd allowed to settle. The face of the filter-plate *d* is then carefully cleaned, by means of the skimming-dish, from all adhering curd, the plug *e* removed from the outer case, and the tap *g* opened. When the top whey is removed, leaving the curd visible, a tub-cloth is laid over its surface, the edges being carefully placed between the curd and the vessel. A pressing-plate, fig. 580, provided with a number of holes on

Fig. 580.



PRESSING-PLATE

Fig. 581.

PRESSING-SCREW.

Fig. 582.

CROSS-ARMS FOR PRESSING-PLATE.

its surface, is then placed over the tub-cloth. The beam *b*, fig. 579, is then made to carry a screw, shown separately in fig. 581, which is worked by the handle *c c*, fig. 579, and the pressure transmitted equally over the whole surface of the plate through the medium of the cross arms, fig. 582, the lower part of which rests on the plate in fig. 580.

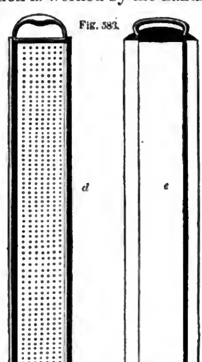
1611. Figs. 579 to 582 are about $\frac{1}{16}$th of the full size. In fig. 583 is given the filter-plate *d*, and the movable plug *e*, on a larger scale.

1612. The price of this apparatus, to hold 90 gallons, is £25; to hold 126 gallons, £32.

1613. *The Cheese-Press* comes next in order of business; and of that machine the varieties are very numerous, though they may all be resolved into two kinds, namely, the stone-press and the "lever-press," of which class the varieties are the most numerous, from the simple lever to the more complicated arrangement of rack, pinion, and levers.

1614. *Stone Cheese-Press.*—An example of this kind is shown in fig. 584: it consists of a strong frame of wood, of which *a* is the sill, 2 feet long, 18

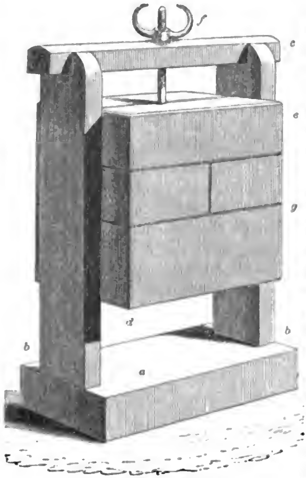
Fig. 583.



FILTER-PLATE AND PLUG.

inches broad, and 4 inches thick. Two uprights *b b* are mortised or dovetailed into it; these are each 6 inches broad by 2½ inches thick, 3 feet high, and are connected by a cross-head *c*, mortised upon the posts. A cubical block of stone *d e* is squared to pass freely between the posts; an iron stem, 1 inch diameter, is fixed into the upper surface of the block, and furnished with a screw at the upper end. It passes through the top bar, and the lever-nut *f* is applied to it for raising or lowering the block *d e*. In each end of the block a vertical groove is cut, corresponding to the middle of the posts; and a baton of wood is nailed upon the latter, in such form and position as will admit the block to rise and fall freely, while it is prevented falling to either side. When put in operation, the block is raised by means of the screw, until the cheese-mould, with its contents, can be placed upon the sill *a* under the block. This being done, the nut is screwed backward till the block rests lightly on the cover of the mould; it is let down by small additions, as the curd consolidates, until it is thought safe to let the entire weight press upon the mould, which is done by withdrawing the nut *f*.

Fig. 584.



STONE CHEESE-PRESS IN PERSPECTIVE.

1615. Instead of the solid block of stone *d e*, which, when left to itself, will always produce the same pressure, it is better to have one block *d g* into which the suspending bolt is fixed, and the remainder of the mass made up of smaller pieces, as shown in the figure, by which means the amount of free pressure can be regulated to the particular size and state of the cheese; or blocks of cast-iron are sometimes used in the form last described, which are more commodious, and less liable to be broken.

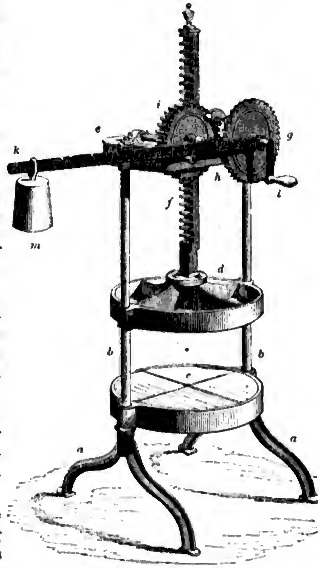
1616. *Lever-Press.*—The next class of this machine, the lever-press, to speak in general terms, possesses the sill of the stone cheese-press in some shape or other, but generally of wood, with two uprights as before; but instead of a heavy block of stone, a simple movable sill of plank is employed, having an iron or a wooden stem attached to it, upon which simple or compound levers are made to act in producing the pressure. An improved form of this lever-press was brought out by the Shotts Iron Company,* made entirely of iron, of a more commodious and compact construction than had hitherto been attempted, and, with slight alterations, is here presented as the type of the class.

1617. *The Combined Lever Cheese-Press.*—This cheese-press of iron is represented in the perspective view, fig. 585, and is constructed in the following manner: *a a* are a pair of cast-iron feet, on which the machine is supported; they have a socket formed at the crown to receive the malleable-iron pillars *b b*. The sill-plate *c* is 18 inches in diameter, cast with two perforated ears, through which the feet of the pillars *b b* also pass, and secure the sill to the feet,—the cross

* *Transactions of the Highland and Agricultural Society*, vol. x. p. 52.

lines in the sill indicate channels for the escape of the expressed whey. The movable sill *d* is of the same size as the one below, with corresponding ears perforated and fitted to slide on the pillars, and having the rack-bar *f* fixed in its centre. A top frame *e*, 18 inches by 9 inches, and 3 inches deep, is seated upon the top of the pillars, where it is fixed by two screw-nuts, and adapted to carry the gearing of the machine.

Fig. 585.



THE COMBINED LEVER CHEESE-PRESS.

1618. The action of the rack and its sill is effected in the following manner: The ratchet-wheel *g* is fixed upon an axle that has its bearings in the top frame; on the same axle is fixed a pinion of eight teeth, not seen in the figure, which works in the wheel *i* of twenty-four teeth, fixed upon an axle which has its bearing also in the top frame; and this axle carries also a pinion of eight teeth, which acts upon the rack, but is also hid from view in the figure. The ratchet-wheel *g* stands clear of the top frame about an inch, and its axle is prolonged beyond the wheel double that extent. The lever *k* is forked at the extremity *g*, and the terminations of the furcation are received upon the axle of the wheel *g*, — the wheel being embraced by the fork of the lever, but the lever moving freely upon the axle. The furcation is also lengthened towards *k* to an extent that receives a pawl at *h*; between and in the throat of the fork, the pawl is jointed upon a pin that passes through both,—the edge of the pawl pointing downwards to catch the ratchet, while it has a nob-handle standing upward, by which it can be conveniently disengaged from its wheel. A small winch-handle *l* is also fitted upon the axle of the ratchet-wheel, and a pin seen near *h* is adapted to a perforation in the top frame, by the insertion of which the descent of the lever is checked, when such is required, and this completes the mechanism of the press.

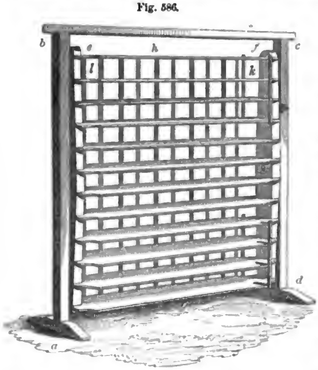
1619. In *pressing* with this machine, the cheese-mould is placed upon the lower sill *c*, and the lever being supported on the pin at *h*, the winch-handle *l* is turned to the left, depressing the rack and its sill till the sill presses upon the cover of the mould. The lever is now lifted by the hand, and the pawl allowed to take into the ratchet; while the lever, being loaded by the weight *m*, will cause the ratchet to turn and produce the descent of the rack. If necessary, this is repeated again and again, till a considerable pressure is produced; and if it is wished that a continued pressure is to go on, the lever is again raised considerably above the horizontal line, and left to descend gradually, following the consolidation of the cheese. If it is wished that the load shall not follow the shrinking of the cheese, the pin *h* is inserted, which, when the lever comes to rest upon it, checks further descent. The amount of pressure is also regulated by the disposal of the weight *m* in the different notches of the lever.

1620. The usual selling price of this machine is £4, when constructed of iron, as in the figure; but with wooden framework, and the rack and other gearing of cast-iron, the price is £3, 5s.

1621. *Cheese-Turner.*—We now notice a useful article in the cheese department of the dairy machinery—the tumbling cheese-rack, or cheese-turner. This machine is the invention of Mr William Blurton of Fieldhall, Uttoxeter, and its merits are believed to be sufficient to warrant its adoption on dairy farms. The object of the machine is to save much of the labour required in the daily turning of a large number of cheeses in the drying-room, and this it does very effectually, for with a rack containing fifty cheeses, they are turned over in very little more time than would be required to turn a single one.

1622. Fig. 586 is a view of the cheese-turner as constructed to stand alone, and on its own feet, though this is not the best mode of constructing the machine. It consists, first, of an external frame *a b c d*, of which the two parts *a b* and *c d* are $6\frac{1}{2}$ feet high, and 7 inches by $2\frac{1}{2}$ inches; they are here represented each with a cross foot *a* and *d*, and connected at top by a top-rail *b c*. If constructed in a cheese-room, the posts should be at once fixed to the floor at bottom, and to the joisting or tie-beams overhead, becoming thus a fixture in so far as regards the external frame. The second part of the machine is a movable frame or rack, formed by the two interior posts *e* and *f*, which are framed upon the twelve shelves *g h*; the posts are 6 feet high, and are again 7 by $2\frac{1}{2}$ inches, the shelves being 7 feet long and 14 inches broad, or more, according to the size of the cheeses manufactured, by 1 inch thick. The shelves extend to $5\frac{1}{2}$ feet in height over all, and are tenoned into and lipped over the posts, and each shelf is finished on both sides with a knife-edged lath, nailed along the back edge; these laths are 2 inches broad, and $\frac{1}{4}$ inch thick at the back, thus increasing the thickness of that edge of the shelves to $1\frac{1}{2}$ inch. As the figure represents a rack that will contain five cheeses on each shelf, a corresponding number of pairs of vertical laths, *k*, are nailed upon the back edge of the shelves. These laths are $1\frac{1}{2}$ inch broad and 1 inch thick, chamfered off to one side to the thickness of $\frac{3}{8}$ inch or thereby at the edges, against which the cheeses are laid, and are checked upon the shelves, and securely nailed. The shelf-frame thus formed is provided with two strong iron gudgeons or pivots fixed in the side-posts at mid-height, and these are received into corresponding holes in the outer or bearing posts, so that the shelf-frame swings poised upon the two pivots; and it is further provided with an iron latch at top and bottom on one end, by which it may be tilted and secured with either the shelf *g* or *h* uppermost. The catches of the two latches are both placed at top on the external post at one side,

Fig. 586.



THE CHEESE-TURNER.

suited to the motion of the shelf-frame, and to prevent its being turned with the back edge of the shelves upward.

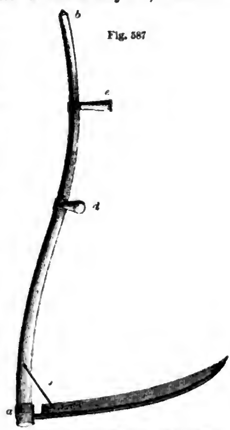
1623. When cheeses are placed upon the shelves, it will be found that the knife-edge laths keep them free of the body of the shelf, and thus permit air to pass under them, while the pair of vertical laths keep the cheese in its proper position on the shelf. The height between the shelves is such as to leave a free space of 1 inch between the cheese and the shelf above it; and whatever number of cheeses may be lying upon the shelves, the simple act of tilting the frame will place every cheese which *was* resting on a shelf, on its opposite side, *upon* that shelf which immediately before was *above* the cheese, but by the tilting is now *below* it. It will be observed, that the vertical laths serve to prevent the cheeses from falling out while the frame is tilting, and each cheese has only to fall one inch in that operation, or from the one shelf to the other, in a reversed position.

1624. It will be also observed, that the fixed external frame is best adapted for an extensive cheese-room, where the racks may be placed in rows extending the length of the room, leaving free passage between the rows. The width of the passage requires to be equal to half the height of the shelf-frame, or 3 feet; a room, therefore, 20 feet wide would contain 4 rows of such *racks;* and if the length were equal to 10 diameters of the cheeses, or containing that number in the length, the room would contain in all 440 cheeses in the best possible condition for their being prepared for market, having free ventilation, and access for the dairy-maids to handle and wipe any cheese at any time.

1625. Section Tenth.—*Manual Implements connected with the above Sections, as Scythes, Forks, Barn Implements, Dairy Utensils.*

1626. *The Common Scythe.*—Grass is cut with the common scythe, which is so well known an implement that a particular description of it seems unnecessary. A few words, however, on the *choice of scythes*, and of the *manner of mounting them*, may be useful. The handle, or *sned* or *sneath*, fig. 587, *a b*, is made either curved to suit the sweep of the instrument by the hands round the body (as in the figure), or straight. The curved sned is usually made of willow, which, being shaped in hot water, and constrained, on being released when the wood becomes cold, retains the shape. Of scythes there are various kinds: the *common* kind keeps its edge but a short time, and in the long run is more expensive than the *patent* kind, which consists of a steel plate riveted between two small rods of iron, and which plate will continue to cut keenly until it is worn to the backbone. The length of the blade of scythes varies from 28 inches to 46 inches. There are besides these other kinds, termed *crown*, *labelled*, and *extra-warranted* scythes.

Fig. 587



THE PATENT SCYTHE WITH BENT SNED.

1627. The price of the common kind varies between these lengths from 2s. 4d. to 3s. 3d. each; and the patent, from 3s. 2d. to 4s. 8d. each. Bent sneds cost from 1s. 3d. to 1s. 6d. each; straight ones, 1s. each. The straight are made of any sort of wood; we have seen good ones of larch.

1628. The blade of a scythe is mounted in this manner: The sned is furnished with an iron ring at the end, to which the blade is attached; the projecting hook at the butt-end of the blade is imbedded flush into the sned by taking away a portion of the wood, and the ring is then slipped over the imbedded hook, and is held tight in its position by an iron wedge as at *a*. The particular position which the blade bears to the sned is determined by measuring the length of the blade *a c* straight along the sned from *a* to *d*, where is fastened the handle for the right hand, and the same length from *d* to *c* fixes the point of the scythe, so that *a d c* forms an equilateral triangle; and of course the blade subtends an angle of 60° with the sned. Theory would advise the placing of the *plane of the blade* parallel with the ground, when the scythe is held as intended for cutting, but practice requires the cutting-edge to be a little elevated above the ground, and above the back of the scythe which sweeps along the surface of the ground; and the reason for keeping the edge elevated is, that it would not only be apt to run into the ground if swung parallel with it, but the scythe would be worked with greater labour, as the stems of the plants to be cut would present an obstacle directly at right angles against the blade, whereas the edge set upwards cuts the stems in a somewhat oblique direction. The blade is still farther secured in its position by the grass-nail *f*, which is hooked by one end into a hole in the blade, and is nailed through an eye by the other to the sned; and one great use of the grass-nail, besides that of strengthening the position of the blade, is to prevent any plants cut from being entangled between the blade and sned. The left-hand handle *e* is placed to suit the convenience of the workman.

Fig. 588.

SCYTHE-STONES.

1629. *Scythe-Stones.*—Scythe-stones, fig. 588, are 14 or 15 inches long, tapering in shape, and of sufficient thickness to fill the grasp of the hand. They are either of a round form, *a*, or square, *b*, and are composed of the same sort of sandstone as grindstones are, and cost 4d. each. They are only occasionally used in order to set a new edge on the blade.

1630. The *scythe-stone* is an essential appendage of the scythe, with which it is kept in proper cutting order. A soft fine-grained sandstone is the proper material from which it should be selected; and as for applying it, it were difficult in words to describe the proper mode of doing so, but the following may suffice to give some notion of the process. The scythe is placed on the left side of the mower, with the point of the blade resting on a small stone on the ground, the heel of the blade and helve being supported by the left hand: the scythe-stone, which is about 14 inches long, is grasped by one end in the right hand, and is thus applied, crossing the blade. The effect of the sharping is produced by making sliding strokes with the stone along the blade on each side alternately downward *towards* the point of the blade. The object of this mode of treatment is based on the principle that the scythe cuts after the manner of a saw: though the teeth are not very prominent, still the fine serrature is there; and to make it cut with the best effect, it must be *hooked* towards the point of the blade, or in the direction of its motion when cutting; and the application of the stone, as above described, produces this direction of the minute teeth in the cutting-edge. The strokes of the stone cannot conveniently be carried over the whole length of the blade at one throw of the hand, hence the sharping begins at the heel, and proceeds downwards; but from the position described, there still remains a few inches at the point untouched, and to reach this part with the stone, the mower lifts up the blade by seizing it about the middle with the left hand, and, bringing it to a horizontal position, the helve still resting partly on the ground and partly against his body, he is enabled to complete the process of sharping. Throughout this operation it is to be specially observed, that, in applying the stone, it must always be held flat upon both sides of the blade: if this is not attended to, either the edge will not be improved, or it will be rounded off; and the consequence of the rounding will be, that the scythe will speedily be unfit for cutting until it be re-ground.

1631. *Scythe Strike or Strickle.* — The *strike* or *strickle*, fig. 589, which is also used in the sharpening of the scythe, principally for giving it a finer edge, though this is very frequently a mistaken notion, is formed of a piece of hardwood, about 15 inches long, one end of which is shaped into a handle; the body of it is sometimes $1\frac{1}{2}$ inch square, but in most cases it is about 2 inches broad by $\frac{3}{4}$-inch thick. It is coated over with granulated emery, imbedded in a cement such as glue; and to produce the best effects, the emery should be of a medium degree of fineness. The strickle being a light instrument, it is always attached to the top of the helve of the scythe, as at *a*, upon a **T**-headed nail, and upon a spike at *b*, and is therefore always at hand, ready to be applied in the event of any accidental injury to the edge of the scythe being sustained; while the stone, from its greater weight, can only be resorted to at the place of starting work, where it lies in readiness. The cost of a strickle is 6d.

Fig. 589.

A SCYTHE STRICKLE.

1632. *Straw-Fork.*—The straw-fork is such as in fig. 590. This fork has rather longer prongs, and is too sharp for a *stable fork*, which is most handy for shaking up straw when about 5 feet in length, and least dangerous of injuring the legs of the horses by puncture when blunt. The united prongs terminate at their upper end in a pointed spike or tine, as better seen in fig. 591, and which is driven into a ferruled ash shaft. This mode of mounting a fork is much better than with socket and nail, the nail being apt to become loose and catch the straw.

1633. *Lincolnshire Steel Straw-Fork.*—Fig. 591 represents the steel fork commonly used in Lincolnshire, without its shaft. This is a light handy implement for working amongst hay and straw.

1634. *Wooden Hay-Fork.*—A simple form of hay-fork, used on the Continent, is illustrated in fig. 592. A piece of wood *a*, of the length and diameter required, is split up at the end to form the two forks *c c*, which are pointed. A

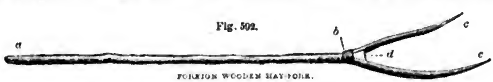
Fig. 590.

THE STRAWFORK.

Fig. 591.

THE LINCOLNSHIRE STEEL FORK.

Fig. 592.



FOREIGN WOODEN HAY-FORK.

ferrule *b* is passed over the end at *c*, and a wedge driven in at *d* to separate the points. This is a very light implement for working among hay or straw.

1635. *Hand Hay-Rake.*—The hand hay-rake is an implement of great simplicity; but though almost elementary in its construction, it has been subjected to numerous variations, chiefly in one point, with a view to its improvement. It consists of a head *c d*, fig. 594, or *g h*, fig. 593, of from 24 to 27 inches in length, made of hardwood, $1\frac{1}{2}$ inch broad in the middle, tapering a little to each end, and from 1 to $1\frac{1}{4}$ inch thick. The head is armed with

Fig. 593.

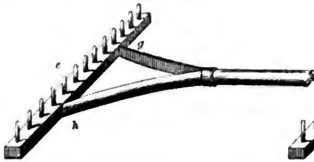
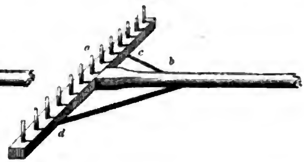


Fig. 594.

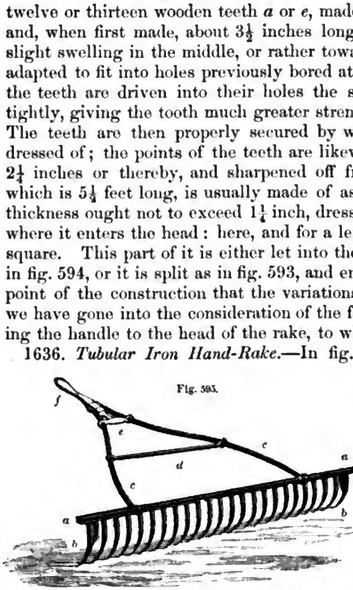


THE HAND HAY-RAKES.

twelve or thirteen wooden teeth *a* or *e*, made of oak or ash $\frac{3}{8}$ inch in diameter, and, when first made, about $3\frac{1}{2}$ inches long. They ought to be formed with a slight swelling in the middle, or rather towards one end, the shorter end being adapted to fit into holes previously bored at 2 inches apart centres; and when the teeth are driven into their holes the swell on the tooth fills up the hole tightly, giving the tooth much greater strength than if it were quite cylindrical. The teeth are then properly secured by wedging, and the wedges and ends dressed of; the points of the teeth are likewise dressed off to a uniform length, $2\frac{1}{4}$ inches or thereby, and sharpened off from the back. The shaft or helve, which is $5\frac{1}{4}$ feet long, is usually made of ash; but as lightness is an object, its thickness ought not to exceed $1\frac{1}{4}$ inch, dressed neatly smooth and round except where it enters the head: here, and for a length of 12 inches, it is usually kept square. This part of it is either let into the middle of the head by a tenon, as in fig. 594, or it is split as in fig. 593, and enters it by two tenons. It is in this point of the construction that the variations have occurred. In par. 13, fig. 7, we have gone into the consideration of the faulty and correct methods of attaching the handle to the head of the rake, to which we now refer the reader.

1636. *Tubular Iron Hand-Rake.*—In fig. 595 we illustrate a form of hand-rake manufactured by Mr Warner Sharman, Melton - Mowbray. In this, great strength is obtained, with considerable lightness, by the employment of tubular iron. The sides, cross-bar, and handle, are so fitted as to take to pieces at pleasure. *a a* is the cross-bar, to which the tines *b b* are fixed; *c c* the side-bars, strengthened by the stay *d*, and passing through eyes of the cross-piece *e*, to which the handle *f* is attached. The dimensions are as follow:—The cross-bar *a a* 5 feet long, of one-inch tubular iron; the extreme length over all, from bar *a a* to point of handle *f*, 5 feet. The length of the stay *d* is 1 foot $10\frac{1}{2}$ inches; the cross-bar *e* 9 inches. The extreme length of tooth, from centre of bar *a a* to the point, is 12 inches; the number of teeth, twenty-four.

Fig. 595.



SHARMAN'S TUBULAR-IRON HAND-RAKE.

1637. *The Sickle.*—The sickle is a very simple, but at the same time, so far as it goes, a very efficient instrument for reaping corn. It is employed in various states, not differing much in the general form, though exhibiting marked differences in the detail; but these varieties are confined under two very distinct forms, the *toothed* and the *smooth-edged* sickles.

1638. *The Toothed Sickle.*—Fig. 596 represents the *toothed* sickle, an instrument so well known that it requires little description here. The blade, in the common toothed sickle, is principally made of iron, but with an edging of steel; the teeth are formed by striking with a chisel and hammer, in the manner of file-cutting, the cutting being only on the lower side; but when the blade has been bent to the proper form, tempered, and ground on the smooth side, the serratures are brought prominently out on the edge of the blade; and as the striking of the teeth is performed in a position oblique to the edge of the blade, at an angle of about 70°, the serratures on the edge acquire what is called a *hook* towards the helve, thus causing the instrument to cut keenly in that direction, when drawn through the standing corn. When the blade has been thus finished, a wooden helve of the simplest form is fitted upon the pointed tine formed at its root for that purpose.

Fig. 596.

THE TOOTHED SICKLE.

1639. *Sorby's Cast-Steel Toothed Sickle.*—The toothed sickle is made with various degrees of curvature and of weight, but chiefly as represented in the figure, and it has been the subject of several patents, chiefly depending on the formation of the blade. One of these is only of a few years' standing. Messrs Sorby and Son, of Sheffield, are the patentees; and the principle upon which their patent is based, is a blade of rolled cast-steel swedged into a form that gives a sufficient degree of stiffness to the blade, without the increase of weight that accompanies the thick-backed or the other patent ribbed-back sickles. In the new patent, the advantage of a small quantity of the very best material—cast-steel—is combined with extreme lightness and a due degree of strength and stiffness, the stiffness arising from the swedged or moulded back.

1640. *The Smooth-edged Sickle.*—The smooth-edged sickle, or *scythe-hook*, as it is sometimes called, differs from the toothed sickle in being broader in the blade, and longer withal, but in curvature it resembles it; and its chief difference lies in being ground on both sides, to form a fine and thin sharp edge.

1641. Like the toothed sickle, the blade has undergone various improvements; and Mr Sorby's cast-steel swedged-blade is also extended to the smooth-edged sickle.

1642. *The Principle of the Curvature of the Sickle.*—In the formation of the sickle, the curvature of the blade is a point of more importance than to a careless observer may appear; and though the ordinary reaper is seldom qualified to judge in this matter, he may feel pleased to be informed, that there is a certain curvature that will give to the muscles of his right arm the least possible cause for exertion, while there are other curves that, if given to the blade of the sickle, would cause him to expend a great amount of unnecessary exertion in the arm, and a consequent unnecessary fatigue would follow. Fig. 597, which represents the smooth-edged sickle, has a curvature approaching very near to that which, in this

Fig. 597.

THE SMOOTH-EDGED SICKLE.

instrument, may be termed the *curve of least exertion;* and throughout that portion of the sickle that performs the cutting process, it possesses this peculiar property, from the following circumstance that, lines diverging from the centre of the handle of the sickle at *a*, and intersecting the curve of the cutting-edge, all the diverging lines will form equal angles with the tangents to the curve at the points of intersection. This property gives to the cutting-edge a uniform tendency to cut at every point in its length, without any other exertion than a direct *pull* upon the helve. Were the curvature less at any point, a pressure of the hand would be required to keep the edge to the work; and were the curvature greater at any point, or on the whole, the exertion to make the cut would be greater, as it would then become more direct, instead of the oblique drawing or *sawing* cut, which, in all cases, is the most effective, and productive of least resistance.

1643. *Dinging-in* or *Bagging.*—A mode of using the smooth-edged sickle has of late years come into some repute, known in Scotland by the provincial term *dinging-in* (striking-in), and in England *bagging.* In this process the sickle is not drawn through the straw, but is struck against it, somewhat in the manner of using a scythe; indeed, the practice originated in the attempt that was made some years ago to introduce the Hainault scythe in the harvest operations of this country, but without success. In the dinging-in practice, the left hand is employed, with its back towards the right, in slightly bending down the grain, and holding it to the blow of the sickle. A man practised in this mode of working will do one-half more work than is usually done in the common way; but the stubble is left less regular, and, except by very expert hands, there is a want of tidiness in the process. It is obvious that this is the same mode of cutting corn as bagging.

1644. *The Common Reaping-Scythe.*—The scythe is also extensively used as a reaping instrument, but more especially in England, and in some of the northern counties of Scotland, chiefly for the barley and oat crops, though in some localities also for wheat. The common hay-scythe is used for this purpose, in most cases, with the addition only of a very light rail or cradle, sometimes attached to the handle, and in other cases to the heel of the blade, as at *a* in the annexed cut, fig. 598, which is the common scythe fitted for reaping. In the scythe mounted in this manner, the use of the rail or cradle will be obvious, being the collecting of the swath into a compact body, and depositing the same in as regular a manner as possible, preparatory to the binding of it into a sheaf.

Fig. 598.

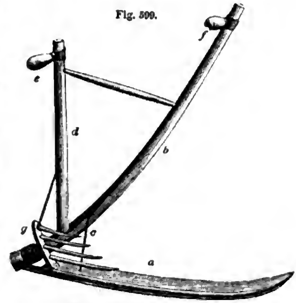
THE COMMON REAPING-SCYTHE.

1645. *The Cradle-Scythe.*—For a considerable period, a scythe, mounted in a different form, has been in use for the purpose of reaping, and it is believed that its introduction can be traced to Banffshire or Aberdeenshire, where the scythe is extensively used for reaping. Some years ago this form of scythe came more prominently before the public,* and for a time gained considerable repute, under the name of the *Cradle-scythe.* Of this form of mounting a reaping-scythe there are many varieties; but they all agree in one point, that of having two short helves, the one branching out of the other, instead of the common long helve or sned. Fig. 599 is a view of the cradle-scythe in one of its most

* *Quarterly Journal of Agriculture,* vol. v. p. 106.

approved forms, wherein *a* is the scythe-blade, *b* the principal helve, to which the blade is attached in the usual way (par. 1628), the hook of the tine being sunk into the wood, and an iron ferrule brought down over the tine, binding it firmly to the wood; but the blade is further supported by the addition of the light stay *c*, termed by mowers the *grass-nail*. The minor helve *d* is tenoned into the principal one, and the two handles *e f* are adjusted by wedges in the usual way to the height and mode of working of the mower. The *cradle*, or rake, consists of a little wooden standard *g*, about 8 inches high, jointed to the heel of the blade, so as to fold a little up or down across the blade; into this is inserted three or four slender teeth, following the direction of the blade, and may be from 6 to 15 inches long: the head of the standard is supported by a slender rod of iron, which stretches about 18 inches up the minor handle *d*, where it is secured by a small screw-nut, capable of being shifted up or down to alter the position of the standard and its teeth to suit the lay of the corn.

Fig. 599.



THE CRADLE-SCYTHE FOR REAPING.

1646. The standard or rake-head was at one time recommended to be made in the segment of a circle,* for which there seems no good reason, either practical or philosophical; but the idea was seized upon, and the cradle-scythe mounted in that form was widely distributed; but instead of this supposed improvement tending to increase the favourable opinion of scythe-reaping, the practice seems rather on the decline; and there is good reason to believe that this malformation of the rake may have had no small share in producing a distaste for scythe-reaping as a practice; whereas, under proper management, and a judicious choice of implements, there can be no doubt of considerable advantages being attainable from scythe-reaping, as compared with the sickle.

1647. It is believed by very competent judges, that the figure here given of the cradle-scythe possesses all the advantages that are derivable from using this instrument; and, in addition to the details already given, we may add that the length of the blade *a*, fig. 599, is from 3 feet 4 inches to 3 feet 6 inches; the left, or principal helve *b* is about 4 feet, the other *d* 3 feet, measuring direct from the heel in both cases; the distance between the helves, where the handles are applied, from *e* to *f*, is 24 inches; and in setting the blade the following rule is to be observed: When the framed helves are laid flat on a level surface, the point of the blade should be from 18 to 20 inches above that surface, and measuring from a point on the left helve *b*, 3 feet distant from the heel of the blade, in a straight line, as at *b*, the extremity of the blade should be also 3 feet distant from the point *b*.

1648. Iron has, in many cases, been substituted for wood in the construction of the helves, but it does not by any means appear to be so well adapted to the purpose as the wooden helves. When constructed of iron, if they are made sufficiently light, there is too much elasticity in the fabric, which is fatiguing to the workman, by reason of the tremor produced at every stroke of the scythe.

1649. *Sheaf-Gauge.*—When corn is cut by the piece in sheaves and stooks or shocks, it is necessary that each sheaf shall have a definite dimension, and, to

* *Quarterly Journal of Agriculture*, vol. vi. p. 30.

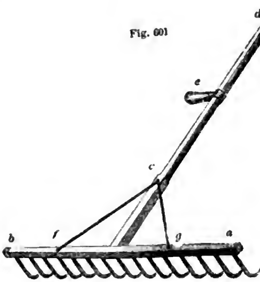
ascertain that, a gauge is requisite. The sheaf should be 3 feet in circumference at the fastened band, or 1 foot diameter. The sheaf-gauge is made of the height of 3 feet, to be used in the hand of the superintendent as a staff. The top is formed of a short cross-head of wood, the shank of rod-iron, the lower part of which, being the gauge, is branched so as the two limbs shall be 1 foot asunder; *a b c d*, fig. 600, the gauge, will thus form a square of 1 foot, which the sheaf at the band shall just fill up, when of the proper size.

Fig. 600.

THE SHEAF-GAUGE

1650. *The Hand Stubble-Rake.*—The gleaning of the stubble is an object of considerable value, and to secure it for the farmer different implements are employed. The principal and most effective of them is the horse-rake, two varieties of which were illustrated in Section Second, Division Second of the Second Book, but in the absence of that machine the hand stubble-rake, fig. 601, is found a very effective implement. The head *a b* is 5 feet long, of good tough ash, 2½ by 2 inches; the helve *c d* may be 6 feet long, of the same material as the head. It should be furnished with a handle *e* that can be fixed in any desired position by driving in a wedge between the helve *c d* and the ring or ferrule at the termination of the handle. The helve is tenoned into the head, and supported by the brace *f c g*. The teeth are of iron, 7 inches in length, and set 4 inches apart, but formed in the lower part so that the bend lies on the ground, which arrangement prevents the points from penetrating the ground and dragging it up and mixing it with the gleanings. The best method of fixing the teeth is by a screw-nut, as in the horse-rake, as they are thereby easily removed in the case of being broken, without risk of injuring the head. It is also advisable to have the ends of the head hooped, to prevent the iron teeth splitting it.

Fig. 601

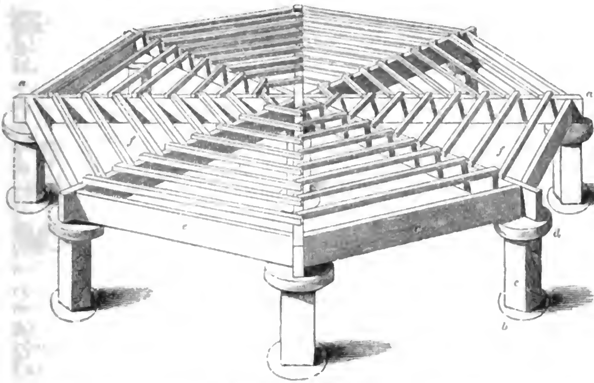


THE HAND STUBBLE-RAKE

1651. In fig. 595 we have illustrated a form of hand-rake which may be used on stubble, constructed of tubular iron.

1652. *The Stathel for Stacks.*—The principal furniture of the stackyard is the "stathel," or "rick-stand." Its immediate use is to keep the stacks off the ground from damp, and to prevent the harbouring of vermin. Stathels are made of stone supports and a wooden frame; of iron supports and a wooden frame; or of iron altogether. The frame is of the form of an octagon, and under its centre and each angle is placed a support. The framework consists of a plank *a a*, fig. 602, 15 feet in length, and of others 7½ feet in length, 9 inches in depth, and 2½ inches in thickness, if made of Scots fir; but less will suffice with larch for stacks of 15 feet diameter. The diameter may be more or less, as the size of the stacks are larger or smaller than 15 feet. The supports consist of a stone *b*, sunk to the level of the ground, to form a solid foundation for the upright support *c*, 18 inches in height, and 8 inches square, to stand upon; and on the top of this is placed a flat rounded stone or bonnet *d*, of at least 2 inches in thickness. The upright stone is bedded in lime, both with the found-stone and bonnet. All the tops of these stone supports must be on the same level. Upon these are placed on edge the scantlings *a a*, to the outer end of which are fastened with strong nails the bearers *e e*, also 9 inches in depth and 2 inches in thickness. The spaces between the scantlings *a* are filled up with fillets of wood *ff* nailed upon them.

Fig. 602.



A WOODEN STATHEL FOR STACKS.

1653. If the wood of the framework were previously preserved by Kyan's or Burnett's process, it would last perhaps twenty years, even if made of any kind of home timber, such as larch or Scots fir.

1654. It has been recommended to divide the frame of the stathels into two parts, so that they might be put under cover when not in use in the stackyard. Were the stathels made removable, they would be more convenient in two pieces than in one: but the propriety of removing them is questionable, when it is accompanied with the necessity of removing the supports also; for it is clear that the supports could not be left standing in the stackyard with the slightest chance of remaining in that position for any length of time.

1655. *Iron Rick-stand Pillar.*—In fig. 603 we give a cast-iron rick-stand pillar, manufactured by Messrs Hill and Smith, Brierly Hall, Staffordshire. These are prepared to receive a framework of wood, the pillars being supplied in sets, the purchaser finding the wooden frame. A set of nine pillars and caps for a stand of 12 feet diameter costs £1, 11s. 6d.; a set of twelve, for a stand of 22 feet, £3, 16s.

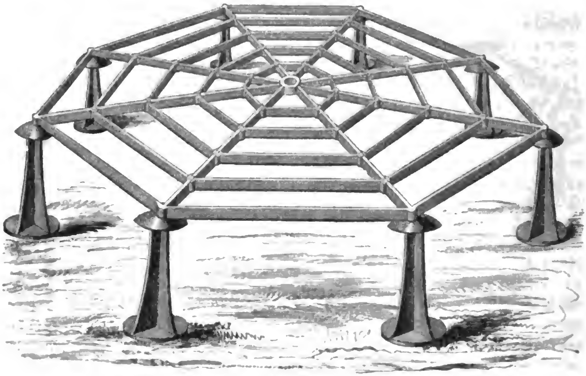
1656. *Iron Rick-Stand.*—The same firm manufactures a circular rick-stand, complete as shown in fig. 604; the price of one 12 feet in diameter, on eight pillars, being £4; one 22 feet in diameter, on twenty-three pillars, £12, 10s. Oblong stack-stands are principally used for hay and barley: for a stand of 12 feet long by 10 feet wide, on nine pillars, the

Fig. 603.

CAST-IRON RICK-STAND PILLAR.

price is £4, 7s. 6d.; for one 42 feet by 20 feet, on forty pillars, £23, 17s. 6d. The peculiar construction of these rick-stands is simply to put them together

Fig. 604.



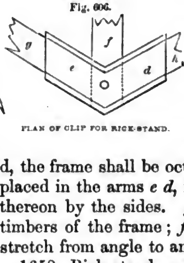
CAST-IRON RICK-STAND.

without the use of screw-bolts or pins. They are vermin-proof, no rat or mouse being able to pass the dome-cap of the pillars, even should it manage—a by no means likely thing—to climb up the iron stalk.

Fig. 605.

ELEVATION OF CLIP FOR RICK-STAND.

Fig. 606.



PLAN OF CLIP FOR RICK-STAND.

1657. *Iron Clips for Rick-Stands.*—Iron clips are useful in erecting rick-stands with iron pillars and wooden framing. A form of this we illustrate in fig. 605: *a* is the dome of the rick-pillar, *b* the central pin, *c* a section of the iron clip which rests on the top of the dome; the plan of the clip is shown at *e*, fig. 606, the angles being such that, when eight pillars are used, the frame shall be octagonal. The timber forming the frame is placed in the arms *e d*, fig. 606, of the clip, and are kept securely thereon by the sides. *g* and *h* show part of the side or boundary timbers of the frame; *f* part of one of the central timbers, which stretch from angle to angle of the octagonal frame.

Fig. 607.

A STACK-TRIMMER.

1658. Rick-stands made of cast-iron, though neat and efficient and durable, must be expensive, and liable to be broken by accidental concussion from carts. Malleable iron stathels would remove the objection of liability to fracture, but not that of expense.

1659. *Stack-Trimmer.*—As each cart is unloaded, the stacker descends to the ground by means of a ladder, and trims the stack, by pushing in with a fork the end of any sheaf that projects further than the rest, and by pulling out any that may have been placed too far in. As the stack rises in height with cart-load after cart-load, the trimming cannot be conveniently done with a fork; a half-inch-thick flat board, about 20 inches in length and 10 inches broad, nailed firmly to a long shaft, fig. 607, is an appropriate instrument for beating in the projecting ends of the sheaves, and giving the body of the stack a uniform roundness or flatness as the case may be.

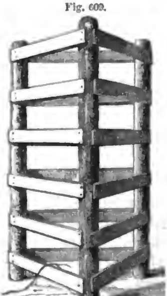
1660. *Stack-Bosses.*—As a safeguard against heating, a structure of wood is erected, around and upon which the stack is built. These structures are in Scotland named *bosses*, which signifies hollows; and the object of using them is to occupy the space which would otherwise be filled with the collected heads of the sheaves of corn, with a void into which air shall be conducted from the exterior of the stack. When stacks are built on bosses erected on stathels, figs. 602 and 604, the air finds ingress into them through the framework of the stathel; but when built upon the ground, a conduit, in the form of a tressle, is formed of woodwork, by which the air is led into the interior of the stack. When such tressles are placed at both sides of a boss, a ventilation is maintained through the body of the stack.

Fig. 608.

A PYRAMIDAL BOSS AND TRESSLE.

1661. *The Pyramidal Stack-Boss.*—The most common form of boss is a three-sided pyramid, formed of three small trees, weedings of a plantation, of larch or Scots fir, tied together at the smaller ends, and the thicker ends placed at equal distances upon the stathel or the ground. Fig. 608 represents one of these common bosses, where the three trees are tied together at the top at *a*, standing about 8 feet in height, and 3 feet asunder from each other; and *b b* are fillets of wood nailed on the trees, for the purpose both of retaining them in the pyramidal form, and of preventing the sheaves falling into the interior of the boss. A tressle *c*, about 2 feet high, is placed on one side to conduct the air into the boss. The inconvenience of this form of boss is, that, as the stack subsides, the sharp apex *a* penetrates through the sheaves lying above it, and in thus disturbing their arrangement, has the chance of disfiguring the form of the upper part of the stack.

Fig. 609.



A PRISMATIC BOSS.

1662. *The Prismatic Stack-Boss.*—Fig. 609 represents a form of boss which we prefer to the pyramidal. It consists of three stems of trees—of weedings—7 feet long, held together in the form of a prism, whose side is 3 feet in width, by fillets of wood of that length being nailed to them. The prism is set on end, and on a stathel only requires to be nailed to it at the bottom; but as a farther means of stability, a spur from each tree should be nailed to the stathel within the prism. On the ground it requires two tressles as well as the pyramidal boss, to complete the ventilation of the air within the stack. The prismatic boss has the advantage over the pyramidal of supporting the top of the stack evenly, when it subsides upon the upper end of the prism, thereby relieving the body of the stack of the weight of its top.

1663. *Stack Boss of Straw.*—Other means than a boss are employed to form a hollow in the heart of a stack, by setting the upright sheaves, which form the foundation of the stack, around a long cylindrical bundle of straw, firmly wound with straw rope; and as the stack rises in height, the bundle is drawn up through its centre to the top, where it is removed, leaving a hole through the height of the stack. This hole creates a current of air through the stack, allowing the heated air to escape, while the cool air enters from below by means of a tressle or stathel.

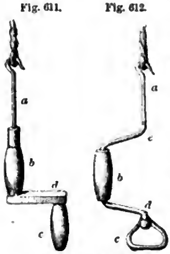
Fig. 610.

THE COMMON THROW-CROOK.

1664. *Common Throw-Crook.*—The throw-crook, fig. 610, is an instrument that has been long in use for the purpose of spinning or twisting straw-ropes, and is one of those primitive inventions that required only the cutting of the first crooked sapling that might come to hand; for though our figure represents an artificially-formed implement, any piece of bent material will answer equally well, all that is required being such a form as will give it the character of what we now denominate a *crank*, and to have a swivel-joint at the end, to allow it to turn freely, and independent of that appendage by which it is attached to the body, or to the left hand of the person who turns it. The implement represented in fig. 610 is made of a piece of tough ash, about 3½ feet long; the bent part is thinned off until it is capable of being bent to the curve, and is there retained by the iron stay *a*, the part *b* being left projecting beyond the stay, for the attachment of the first end of the rope that is to be made. The end *c* is furnished with ferrule and swivel-ring, by which it is attached to the person, by a cord passed round the waist, or it is held in the left hand. In using the implement, the rope-maker is stationary, usually sitting beside the straw, and the spinner moves backward as the rope extends.

1665. Fig. 611 represents another form of throw-crook, where the hollow cylinder of wood *b* is held in the left hand of the twister, and on moving round the handle *d* with the right hand, the iron shank *a* is made to revolve and twist the straw attached to its hooked end into a rope.

Fig. 611. Fig. 612.

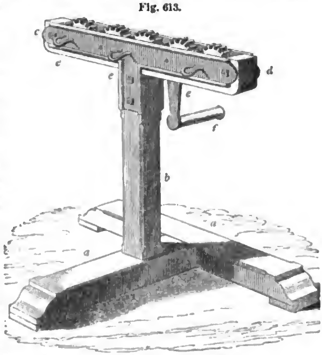


STRAW-ROPE TWISTERS.

1666. Fig. 612 gives still another form of throw-crook, where the iron ring *c* is held in the left hand of the twister, and the hollow cylinder of wood *b* grasped by the right hand, and made to revolve round the line *d e* by means of the swivel-joint at *d*, and to cause the revolution also of the iron shank *a*, with its hook to which the straw is attached, which is to be twisted into a rope.

1667. *Straw-Rope Spinner.*—The straw-rope spinner, fig. 613, is a machine of recent introduction to the operations of the harvest season, and is of considerable importance in facilitating the process of straw-rope-making. Comparing it with the old instrument, the *throw-crook*, fig. 610, the advantage is considerable; for with that two people must be occupied in the making of one rope, whereas with the spinner four people only are required to make three ropes, being a saving of one-third of the time occupied by the old practice. The spinner has been constructed in various forms, though exhibiting but two distinct varieties of the machine, the first distinguished by the spinner being stationary, and the ropemaker moving away from him; the second, by the ropemaker being stationary, and the spinner moving away from him. The spinner being stationary is found to be the best in practice, and we have therefore chosen an example of it for illustration. Fig. 613 is a view of the machine, consisting of a sole-frame, *a a*, measuring about 2 feet each way, with an upright post *b* tenoned into the sole, and carrying the cross-head *c d*. The cross-head is a hollow box or case, adapted to contain the machinery of the spinner, consisting of 5 light spur-wheels, about 6 inches diameter, placed as seen in the case *c d*. Of these, the central and the two extreme wheels are mounted upon axles, which terminate in the hooks *e e e*, the other two wheels being merely placed intermediate, to produce revolution in the three principals in one direction. A winch-handle *f* is fixed upon the axle of the central wheel, on the side opposite to the hooks; and to prevent the machine from moving with the strain of the ropes, a few stones, or other weighty substances, are laid upon the sole-frame *a a*. The machine is then put in operation by the driver turning the handle *f*, and the three ropemakers, each with a quantity of straw under his arm, commences his rope by binding a few straws round the hook appropriated to himself. He then proceeds backward, letting out the straw as he advances, and the rope takes the twist, until the length required is completed, when each man coils up his rope into an oval ball.

Fig. 613.



THE STRAW-ROPE SPINNER.

1668. Some machines of this form are mounted on wheels, thereby coming under the character of the second kind (par. 1667), where the ropemaker is stationary; but great inconvenience must attend any attempt at working in this manner.

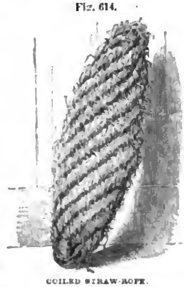
1669. Another form of the machine adapted to work as one of the second kind (par. 1667), is that which is strapped to the body of the spinner, he moving away from the stationary ropemakers. This method also is attended with inconvenience, especially to the spinner, who, having the machine strapped in front of his body, the handle being at the end, and the machinery consisting of bevel-gear, the handle is brought so near to his body that much of the muscular force of the arm is lost by this misapplication.

1670. By using a well-constructed machine for straw-rope spinning, not only is there a saving of expense effected, but the ropes are much better twisted, and, of course, stronger than those made by the old implement.

1671. The price of a straw-rope spinner is from £2, 5s. to £2, 10s.

1672. Fig. 614 represents a rope of straw coiled up for use. The spinner, after he has let out as much straw as makes the length of rope required for the size of stack upon which it is to be used, winds it up upon his left hand and arm into a coil of the form and mode represented in the figure, and which is so firmly put together

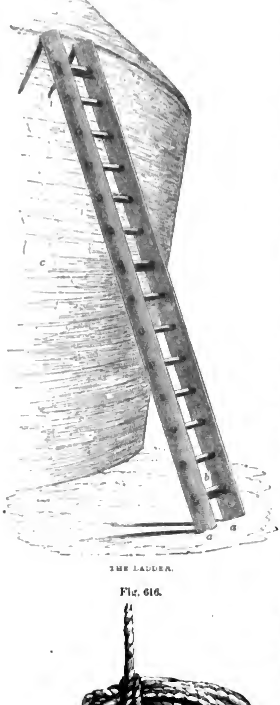
Fig. 614.



COILED STRAW-ROPE.

that a man can throw such a coil to the top of the highest stack in the stackyard to the man who is thatching the stack.

Fig. 615.



THE LADDER.

Fig. 616.

COILED CART-ROPE.

1673. *Ladders.*—Ladders are best formed of tapering Norway pine spars sawn up the middle. A useful form of ladder for farm purposes is shown in fig. 615, where the rounded parts of the divided spar *a a* are placed outmost, and are connected together by steps *b*, of clean ash driven through auger-holes, and firmly wedged into the spars. The steps are 9 inches apart, and are 16 inches long at the bottom, and 13 inches at the top, between the spars of a ladder of 15 feet in length, which is the most useful size for the use of a stackyard. To prevent the ladder from falling to pieces, in consequence of the shrinking and loosening of the round steps, a small rod of iron is placed under the upper, middle, and lower steps, where its ends are passed through the spars, keeping them asunder by means of its shoulders, and holding them firmly together with nut and screw at each of its ends. When well finished and painted, such a ladder will last many years. Longer ladders are used for reaching the tops of stacks.

1674. *Coil of Cart-Rope.*—Fig. 616 represents the mode in which the rope of a harvest cart is coiled up after the load of corn has been brought into the stackyard from the harvest field. Two of such ropes are suspended at the hind end of each cart.

1675. *The Flail.*—The flail consists of two parts, the ***hand-staff*** or helve *a b*, and the ***supple*** or beater *b c*, fig. 617. The hand-staff is a light rod of ash about 5 feet in length, slightly increased in breadth at the lower extremity, where it is perforated for the passage of the thongs that bind the beater to it. The beater is a rod of from 30 to 36 inches in length, frequently also made of ash, though a more compact wood, such as thorn, is better adapted for it. If not properly applied, the ash beater will very soon separate into thin plates, which are portions of the concentric layers of the wood, and their separation arises from the beater falling upon the flat or convex side of these annular layers—or the reed of the wood, as vulgarly called. To prevent this disintegration of the wood, the beater should be constructed to fall upon the *edge* of the segmental portions of the *reed*, which is easily accomplished in its formation. The usual form of the beater is cylindrical, but frequently thickened a little towards the extreme end, the diameter being from $1\frac{1}{4}$ to $1\frac{1}{2}$ inch. For the most part, it is attached to the hand-staff by a strap of leather, or more frequently of hide untanned. When mounted in this manner, the beater is formed with two projecting ears, standing at right angles to the side on which it is intended to fall, and about $1\frac{1}{2}$ inch from the end by which it is attached, serving the purpose of retaining the end of the beater within the strap. The strap is about 8 inches long and $1\frac{1}{2}$ inch broad; it is bent over the end of the beater, and the tails brought to embrace the sides of it beyond the ears. The strap being previously perforated with four holes in each tail, it is bound by a thong of leather laced through the holes and round the neck of the beater; the upper turn of the lacing-thong catching the ears, prevents the strap from slipping off. The strap, thus applied, forms a loop standing about 1 inch beyond the end of the beater; and through that, and the perforation in the end of the hand-staff, another and stronger thong, sometimes made of eel skin, is passed several turns and secured, forming thus a kind of loose swing-joint that allows free action to the beater in its gyration round the head of the thrasher, and its descents upon the thrashing-floor.

Fig. 617.

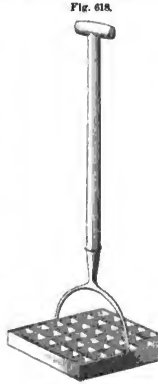
THE FLAIL.

1676. Another mode of mounting the beater is by applying a strap of iron in place of leather, which is fixed to the wood by riveting, leaving a loop as before, which must be nicely rounded and smooth, to prevent the too rapid chafing of the thong by which it is bound to the hand-staff, in the same manner as described above. Fig. 617 given here exhibits the iron strap above *b*.

1677. For an explanation of the action, and of the proper form of the beater of the flail, see par. 8, fig. 2.

1678. *The Hand-Hummeller.*—In the smaller class of farms, hand-hummellers are pretty generally used, and are of various forms, but all retaining one principle of construction and of effect. They are round, square, and oblong; but in all three forms they consist of a number of parallel bars of iron, placed in a frame of one of the forms above named. Fig. 618

Fig. 618.



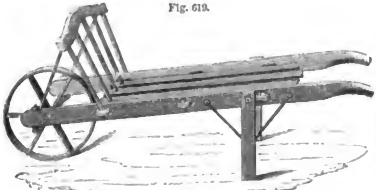
THE HAND-HUMMELLER.

is a square hummeller in perspective. It consists of a square frame of iron, 12 inches each way, 2 inches in depth, and $\frac{1}{8}$ inch thick. Bars of similar dimensions are riveted into the sides of the frame, and crossing each other, forming compartments of from $1\frac{1}{2}$ inch to 2 inches square. A branched iron stem is riveted to the frame below and at top, and forms a socket into which a wooden helve is fixed, having a cross-head by which it is held in the hand.

1679. Such hummellers are frequently made with parallel bars only, in which case they are less expensive, but much less effective.

1680. *Corn-Barrow.* In fig. 619 is shown the corn-barrow, a very convenient means of conveying the sheaves from the stack to the barn to be thrashed, the construction of which is so obvious that a specified description seems unnecessary, farther than that it is about 6 feet in length, and stands $2\frac{1}{2}$ feet in height to the top of the slanting bracket. The sheaves are laid *across* the barrow in rows, with the corn and butt-ends alternately, and they are kept from sliding off in the act of being wheeled, by the slanting bracket which is supported by iron stays. In this way, from ten to fifteen sheaves, according to their bulk, may be wheeled away at once by a woman. The legs of the barrow are also strengthened with iron stays.

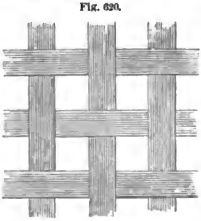
Fig. 619.



THE CORN-BARROW.

1681. *Riddles.*—The most complete implements for separating heavy articles from corn of any kind are *riddles.* They are formed either entirely of wood, or partly of wood and wire. Wooden riddles have long been in use, though, we believe, in the hands of a skilful riddler, the wire riddle makes the best work. The wooden are made of fir or willow, but American elm is the best. The wire riddles have hitherto been made of iron wire, on account, perhaps, of its cheapness; but we should suppose that copper wire would make a better and more durable riddle. A riddle, whether of wood or wire, consists of a bottom of open meshwork, and of a cylindrical rim of wood, the diameter of which is usually 23 or 24 inches, and its depth 3 inches. Rims are made either of fir, or oak, or beech, beech being most used. In fir rims, the wooden withes of the bottom are passed through slits, thereby endangering the splitting of the rim itself all round, which not unfrequently happens; but in the oak rim the withes are passed through bored holes, which never cause splitting. There is little danger of wire splitting the rims of any sort of wood.

Fig. 620.



THE WOODEN WHEAT-RIDDLE.

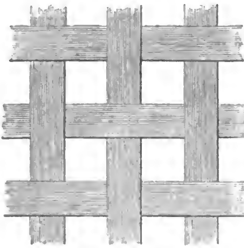
1682. The following figures of riddles are portions only of the bottom of each kind, but the meshes are at full sizes, according to the grain to be riddled.

1683. *Wheat Riddle of Wood,* fig. 620.—The meshes of this riddle are a quarter of an inch square; the breadth of the wood splits three-sixteenths of an inch, and its price is 3s. 6d. with an oak rim.

1684. *Wooden Barley-Riddle,* fig. 621.—This riddle has a mesh of five-sixteenths of an inch square, the breadth of the withes being a quarter of an inch. The price is 3s. with an oak rim.

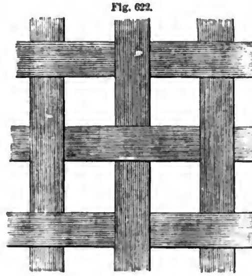
1685. *Wooden Riddle for Oats,* fig. 622, with three-eighths of an inch square of mesh, and the breadth of the withes a quarter of an inch. The price is 2s. 4d. with an oak rim.

Fig. 621.



THE WOODEN BARLEY-RIDDLE.

Fig. 622.

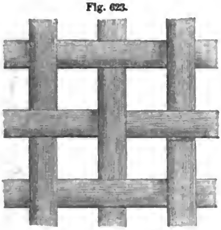


THE WOODEN OAT-RIDDLE.

1686. *Wooden Riddle for Beans*, fig. 623, having five-sixteenths of an inch square in the mesh, with withes of three-sixteenths of an inch in width. The price is 3s. 6d. with an oak rim.

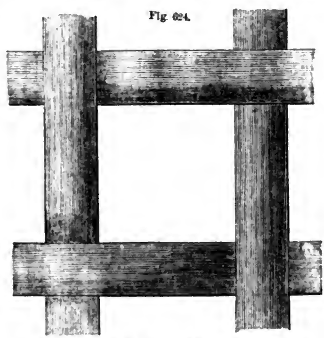
1687. *Wooden Riddle for Roughs.*—For riddling the roughs of wheat and oats—

Fig. 623.



THE WOODEN BEAN-RIDDLE.

Fig. 624.

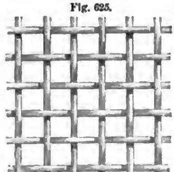


THE WOODEN RIDDLE FOR THE ROUGHS OF WHEAT AND OATS.

the roughs of barley not being riddled—a wooden riddle, fig. 624, has meshes of one inch square, and the breadth of the withes three-eighths of an inch. The price is 2s. with an oak rim.

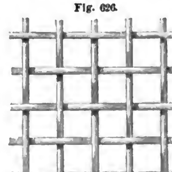
1688. *Iron-wire Riddle for Wheat*, fig. 625. This riddle has 25 meshes in the square inch, including the thickness of the wires. The price is 5s. with a beech rim.

Fig. 625.



THE IRON-WIRE WHEAT-RIDDLE.

Fig. 626.



THE IRON-WIRE BARLEY-RIDDLE.

1689. *Iron-wire Riddle for Barley*, fig. 626, having 16 meshes to the square inch, including the thickness of the wire. The price is 4s. with a beech rim.

1690. A *barley* wire-riddle answers for riddling *beans*, but an opposite process is performed,—the small and shrivelled beans and other refuse pass through the meshes, while the good grain is left in the riddle, together with any lumps of clay and stones that may have accompanied the good grain, and which must be removed by the hand.

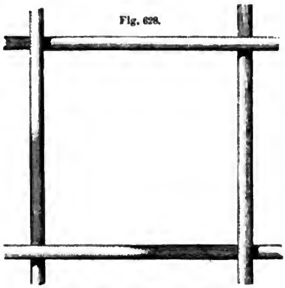
Fig. 627.

THE IRON-WIRE OAT-RIDDLE.

1691. *Iron-wire Riddle for Oats*, fig. 627, having 12 meshes to the square inch, including the thickness of the wire. The price is 3s. 6d. with a beech rim.

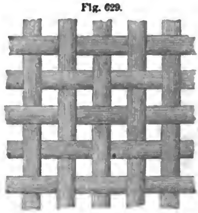
1692. *Slap Riddle.*—Fig. 628 is a wire riddle for roughs, having the meshes 1½ inch square. The price is 2s. 6d. with a beech rim. Riddles for roughs are also called *slap-riddles*. When elevators are used in a thrashing-machine, no slap-riddles are required.

Fig. 628.



THE IRON-WIRE RIDDLE FOR ROUGHS

Fig. 629.



THE WOODEN SIEVE.

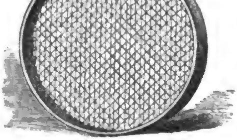
Fig. 630.

THE IRON-WIRE SIEVE

1693. *Wooden Sieves.*—Fig. 629 is a wooden sieve for sifting out dust, earth, and small seeds from corn, having meshes of one-eighth of an inch square, and the breadth of the withes also one-eighth of an inch. The price is 3s. 6d. with an oak rim.

1694. *Iron-wire Sieve.*—Fig. 630 is an iron-wire sieve, having 64 meshes to the square inch, including the thickness of the wire. The size is 22 inches diameter, called No. 8, and, with a beech rim, is sold for 5s. 6d.

Fig. 631.



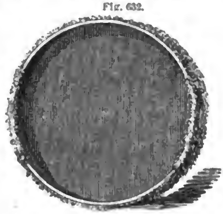
TRIANGULAR MESHED IRON-WIRE SIEVE

1695. In fig. 631 is illustrated a triangular-meshed iron-wire sieve, with an oak rim.

1696. These are all the sizes and varieties of riddles and sieves required on a farm. Of slap-riddles and sieves, only one of each size is used; but of the riddles for wheat, barley, oats, and beans, two of each kind are required, whether of wood or wire. We have tried both kinds, and prefer the wire, as making better work, although we are aware they require more dexterous riddlers, to use them with advantage, than the wooden riddles.

1697. *Wechts* or *Maunds.*—For taking up corn from the bin or floor, wechts, of the form of fig. 632, are made either of withes or of skin attached on a rim of wood. One of fir withes, with a rim of oak, costs 2s. 6d. A young calf's skin with the hair on, or a sheep's skin without the wool, tacked to the rim in a wet state, after becoming dry and hard, makes a better and more durable wecht than wood.

Fig. 632.



WECHT OR MAUND.

1698. Wechts should be made of different sizes; two as large as two fulls shall fill the bushel with ease, and others of smaller diameter, and less depth of rim, to take up the corn from the fanners, to give to the riddlers, or from the bin to supply the hopper of the fanners with corn.

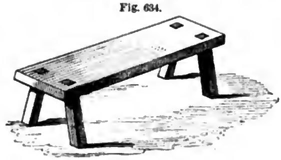
1699. *Barn Basket.*—Baskets of close and beautiful wicker-work, such as fig. 633, are used in barns in parts of England instead of wechts.

1700. *Barn Stool.*—A stout four-legged stool, 2½ feet long, 9 inches broad, and 9 inches high, as fig. 634, made of ash, is useful in a barn, to allow the women to reach the hopper of the fanners easily. For want of a stool the inverted bushel is often taken to stand upon, much to its injury.

Fig. 633.

THE CORN-BASKET OF WICKER-WORK.

Fig. 634.



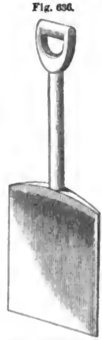
THE BARN STOOL.

1701. *Barn Hoe.*—A wooden hoe, fig. 635, made of plane-tree, 7 inches long, and 4 inches deep in the blade, fixed to a shaft 9 inches long, is easier and quicker than the hands to fill wechts with corn from the floor.

Fig. 635.

THE BARN WOODEN HOE.

Fig. 636.



THE CORN-SCOOP.

1702. *Wooden Scoops.*—A couple of wooden scoops, such as fig. 636, to shovel up the corn in heaps, are indispensable implements in a corn-barn. The scoop is 3 feet 3 inches in height, with a head like a common spade; a helve 18 inches in length, and the blade 14 inches wide and 16 inches long. The blade, helve, and handle, are all of one piece of wood, of plane-tree, the belly of the scoop being a little hollowed out, and its back thinned away to the sides and face. This is a convenient size of scoop for women's use, and who have most occasion to use it, and it is also light.

1703. In the granaries in towns, scoops are made longer, with a handle of a separate piece of ash, and, consisting of more than one piece of wood, are clumsy implements.

1704. A wooden scoop does not injure a floor as much as an iron spade, and better retains the corn upon its blade when used.

1705. *Brooms.*—Brooms are useful implements in a steading, to sweep the different sorts of floors, and they are formed of materials best suited to clean the particular sort of floor. For sweeping the floor of causewayed or paved stables and byres, the twigs of the birch-tree form the most elastic and durable brooms, such as is shown in fig. 637. They are tied together with stout twine in bundles of about 4 inches in diameter at the tied end, and 2 feet in length. A wooden handle of about 3 feet in length is driven into the tied end, and is kept in its place by a pin passed through it and the twigs. The sweeping end receives such a trimming with the knife as to give it a flattened face to the ground sloped away to a point.

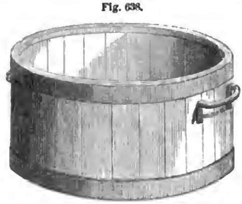
Fig. 637.

LONG-SHANKED STABLE-BROOM.

1706. *Barn Brooms.*—The most handy broom for a corn-barn is made of half-dried twigs of broom, of the form of the stable-broom, fig. 637, without the long shank.

1707. *The Imperial Bushel.*—Corn is now invariably measured by the imperial bushel. It is of cooper-work, made of oak and hooped with iron, and, according to the Weights and Measures Act, must be stamped by competent authority before it can be legally used; and, having been declared the standard measure of capacity in the country for dry measure, it forms the basis of all contracts dependent on measures of capacity when otherwise indefinitely expressed. By 5th Geo. IV., c. 74, sec. 15, the bushel must contain just 2218.19 cubic inches, though its form may vary.

Fig. 638.

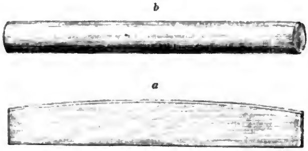


THE IMPERIAL BUSHEL OF A CONVENIENT FORM.

1708. The form represented in fig. 638 we consider most convenient, being somewhat broader at the base than at the top, and furnished with two fixed handles. It is not too broad for the mouth of an ordinary half-quarter sack, nor too deep to compress the grain too much; and its two handles are placed pretty high, so that it may be carried full without the risk of capsizing.

1709. Some bushels are made inconveniently broad for any sack, for the sake of being shallow, that the corn may not be compressed in them. We have seen others spread out so much in the mouth as to render them unsteady. Some have no handles at all, and are obliged to be lifted by the arms. Others have only one handle for the person who overturns the bushel to lay hold of, and that sometimes a jointed one, and there being no handle on the other side for the sack to pass under it, the sack is apt to slip over the mouth of the bushel while being emptied. Others have the handles too low for the sack to pass under in the act of the bushel being emptied. These different modes of making bushels become essential conveniences or inconveniences when much corn has to be measured up in a short time; and when convenience is studied in the form of the bushel, it contributes much to save time.

Fig. 639.



THE FLAT AND CYLINDER CORN-STRIKES.

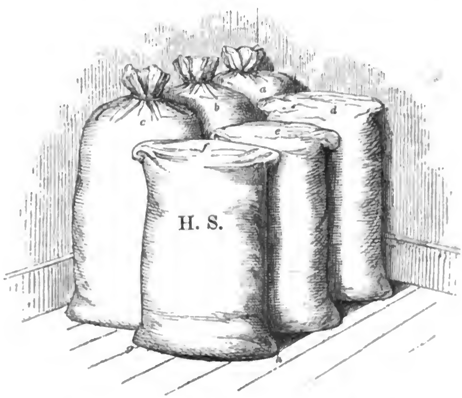
1710. *Corn-Strikes.* — In connection with the bushel is the strike for sweeping off the superfluous corn above the edge of the bushel. It is usually made of two forms; the one a flat piece of wood, like *a* in fig. 639; the other of the form of a roller, like *b*. The Weights and Measures Act prescribes that the strike shall be of a round form, of a piece of light wood, 2 inches in diameter; but he who put the notion into the heads of those who drew up the Act, that this is the best form of strike, must have had little experience of using one. If the object is to separate one stratum of grains of corn from another—and this is the only object of using a strike—the *sharp* edge of the flat strike is evidently best fitted for the purpose. A cylinder, when passed with a uniform motion over a bushel, though not rolling, must push down some of the grain that is in front, under it; and, if it is *rolled* across the bushel, it must press down still more grain, in the manner of a roller passing over clods in friable land, and, of course, *make* the bushel hold more grain than it would naturally do. We would advise all sellers of grain to use the flat strike, whatever purchasers may wish them to do.

1711. On striking wheat, the strike is drawn straight across the bushel, the grains being nearly round, and yielding easily to the forward motion of the strike; but in the case of barley, oats, pease, and beans, the strike should be moved across the bushel in a zigzag manner, because, those grains being large, long, or rough, a straight motion, particularly a rapid one, is apt to tear away some of them to a level below that of the edge of the bushel.

1712. The strike should be made of wood in the best seasoned state, and of that kind which is least likely to lose its straightness of edge, while it should be light to carry in the hand, and hard to resist blows. Perhaps plane-tree may afford the nearest approach to all these properties.

1713. *Sacks of Corn in a Barn.*—To make sacks of corn stand so as each may be taken away with ease from a number, they should be set, the first, one in a corner, with one shoulder against one wall, and the other shoulder against the other wall, as seen at *a*, fig. 640; and every sack in the same row, as *b* and *c*, will stand with the left shoulder against the wall, and

Fig. 640.



FILLED SACKS AS THEY SHOULD BE PLACED ON THE BARN FLOOR.

the right shoulder against the side of the sack set down before it. In the succeeding row, the first sack, as *d*, will have its right shoulder against the wall, and its left shoulder against the side of the first sack *a* that was set up in the corner; and the succeeding sacks, *e* and *f*, will have their left

2 I

shoulders in the hollows between the sacks, *b* and *c*, in the first row, and their right shoulders against the sides of the sacks that were set down just before each of them; and so on, row after row. In short, the sacks stand shoulder to shoulder, instead of side to side. Now, the utility of this arrangement is, that the sacks, in the first place, are as closely set together as they can possibly be; for the left shoulders of *d* and *e*, as may be seen, fill up the hollows between the right shoulders of *a b* and *b c*. In the next place, as each sack is removed in the reversed order in which they were placed, it presents its broad side either to the barrow to be wheeled away, without the slightest entanglement with any other sack, or to be lifted at once as it stands upon the man's back, without the usual trouble of having to be kneed forward to a more convenient spot. Thus, look upon *f*, with the initials H. S. upon it, the last-placed sack, and the first to be removed. It is obvious that its side is presented in the most proper position for the sack-barrow; and its lower corners *g* and *h* are quite ready for the hands of the persons who are to assist in raising it to a man's back.

1714. The figures show also the difference between tight and slovenly sacking-up of corn: *f* shows a slackness of putting the first bushel into it, where there are creases between *g* and *h*, and the corners at *g* and *h* project too much out, because the corn above them is too slack. On the other hand, *d* shows a well-filled sack. When filled sacks are wheeled aside, their mouths should be folded in and closed up, as represented in the outer row *d e f*. On tying sacks, which they must be when intended to be sent away by cart, the tie should be made as near the corn as possible, whatever proportion of the sack may be left over, in order to keep the whole sack firm, as seen in *a*, *b*, and *c*.

1715. *The Sack-Barrow.*—Sacks, when filled, are most conveniently placed in any part of the barn by means of a barrow made for the purpose. A good form of one may be seen in fig. 641. Its height is 3½ feet, and its breadth over the wheels 1½ foot. The frame *a* is made of ash, the wheels of cast-iron; and the scoop *b*, and the shields *c*, which save the sacks rubbing against the wheels, are made of wrought-iron. To be handy, the sack-barrow should stand upright of itself, as seen in the position in the figure.

Fig. 641.

THE SACK-BARROW.

1716. There are two modes of using the sack-barrow—one when the sacks stand upright on being filled, and the other when they stand as in fig. 640. On taking hold of one of the handles *a* with the right hand, behind the wheels, the left hand seizes the mouth of the sack, and pushes it so far off as to allow the scoop *b* of the barrow to pass between the bottom of the sack and the floor; and then, on pulling the sack towards the barrow, while the foot on the axle pushes the barrow forward, the sack is placed on the scoop and is ready for removal. In the case of the sacks, as in fig. 640, all that is required is to push the scoop *b* with the foot under the bottom of the sack *f*, and to pull the sack upon the barrow.

1717. *Lifting Sacks of Corn.*—There are three modes of lifting a sack to a man's back. One is, for the person who is to carry the load to bow his head down in front of the sack, placing his back to its broad side, and bending his left arm behind his own back, across his loins, and his right hand upon his right knee, to await in this position the assistance that is to be given him. Two people assist in raising the sack, by standing face to face, one on each side of it, bowing down so as to clasp hands across the sack near its bottom, as from *g* to *h*, fig. 640, below the carrier's head, and thrusting the fingers of the other hands into the corners *g* and *h*, which yield and go inwards, and thereby afford a firm hold. Each lifter then presses his shoulder against the edge of the sack, and with a combined exertion upwards, which the carrier seconds by raising his body up; the bottom of the sack is raised uppermost, and the tied mouth downmost, resting against the back of the carrier. The lifters now leaving hold, the carrier keeps the sack steady on his back, with his left arm across its mouth.

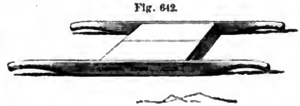
1718. Another plan is, for the carrier to lay hold of the top of the shoulder of the sack with both his hands, his arms crossing each other. His two assistants do as directed before; and while they lift the sack between them, the carrier quickly turns his back round to the sack and receives it there, retaining his firm hold of the parts he had at first.

1719. A third plan is for the assistants to raise the sack upon another one, and then the carrier lowers his back down against the side of the sack, laying hold of its shoulders, over his own shoulders, and rising up straight with it on his back. In all these cases a firmly filled and tied sack is the most easily carried.

1720. The last plan requires most strength from the carrier, he having to rise up with the load; the second most from the lifters, they having to lift the load up; and in the first the strength of both parties is nearly equally divided.

1721. *The Sack-Lifter.*—The sack-lifter, fig. 642, is the hand-barrow of the corn-barn. It simply consists of two pieces of ash, 3 feet 9 inches long, terminating at both ends in the form of handles, clear of the floor, well united together at 15 inches apart, by means of three cross-bars of wood tenoned and mortised into the handles. A boarding is placed over the bars for the sacks to stand upon. The sack is placed on the lifter on the floor, and two persons lift the sack with the lifter as high as to be on a level with the man's back who is to carry it.

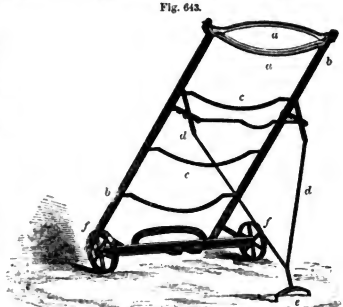
Fig. 642.



SACK LIFTER.

1722. *Gilbert's Sack Filler and Lifter.*—In fig. 643 we illustrate an apparatus, patented by Mr Gilbert, to enable one person to fill sacks with corn, and to lift them. The sack has its mouth expanded and held open by the two jointed clamps or bars *a a*, and is sustained throughout its length by the bars *b b*, and cross-bars *c c*. The stay *d d* is jointed to the bars *b b*, and rests on the floor at its lower extremity at *e*. Wheels, *f f*, are provided, by which the frame and filled sack can be transported from place to place. The length of the bars *b b* is 4 feet 5 inches; the length of elliptical aperture in which the sack is held is 30 inches, and its breadth 12 inches; the diameter of wheels, *f f*, 8 inches. As manufactured by Messrs Richmond and Chandler, the price of the frame without wheels is 23s.; with wheels, 32s.

Fig. 643.



GILBERT'S SACK FILLER AND LIFTER, IN PERSPECTIVE.

1723. *Potato-Graip.*—When potatoes are raised from the drill by the hand, the potato-graip, fig. 644, is the best implement for the purpose. It consists of three flattened prongs of iron, to which is attached a socket, in which a stout helve with a short cross-head is fastened by means of a nail. This graip is used by inserting it into the side of a drill of potatoes with a push of the foot, and the graipful of earth thus obtained is turned over in the hollow of the drill, where the potatoes are exposed to view and gathered. As the raising of potatoes with this graip is a laborious work, men only use it. The price is 3s.

Fig. 644.

POTATO-GRAIP.

Fig. 645.

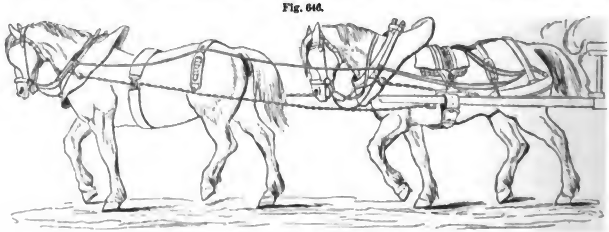
POTATO-BASKET.

1724. *Potato-Basket.*—As the potatoes are exposed to view by the potato-graip, the potato-basket, fig. 645, is used by women and youngsters to gather them in. The basket is made of wicker-work, of a round shape, and as small as easily to be carried about in one hand, whether filled with new taken-up potatoes or potato sets.

1725. *Potato Brander-Shovel.*—A shovel, with a helve and cross-head, having its blade made of narrow bars of iron, as close set together as to retain ordinary-sized potatoes, but to let through small ones, as also earth and stones, is a useful implement at a potato-pit when potatoes are being prepared for the market.

1726. *English and Scotch Cart-Harness.*—Fig. 646 represents the Scotch mode

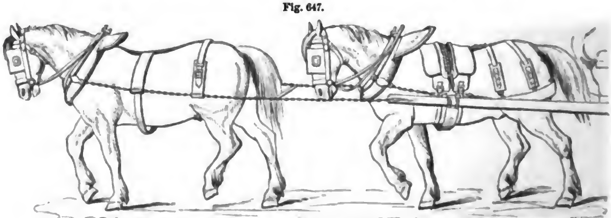
Fig. 646.



SCOTCH MODE OF YOKING A DOUBLE CART.

of yoking horses to a double horse-cart, and fig. 647 shows the English mode of

Fig. 647.



ENGLISH MODE OF YOKING A DOUBLE CART

doing the same. The component parts of the harness consist of the same in both countries—namely, a bridle, collar, haims, back-band, belly-band, and rump-strap for the trace-horse; and bridle, collar, haims, saddle, belly-band, and breeching for the tram horse. Two distinctive particulars, however, may be observed between the two modes of yoking. In the Scotch mode, fig. 646, double reins are employed to guide the horses when the driver may choose to ride on the cart, while the English mode affords no reins. On the other hand, both the trace and tram horses of the English mode of yoking, fig. 647, are provided with cruppers, while the Scotch mode dispenses with cruppers. Cruppers are disliked for farm-horses in Scotland, as they are apt to gall the skin round the onset of the horse's tail.

1727. *The Hay-Knife.*—Fig. 648 affords a good idea of a hay-knife. The hay-knife is used for cutting off a portion of the hay-stack when hay is wanted for consumption. It consists of a sharp-edged broad blade of steeled-iron, with a swedged back and sharp point, having a tine attached to the swedge. The handle consists of a double-handed cross-head, through the middle of which the tine of the blade is passed, and fixed by riveting.

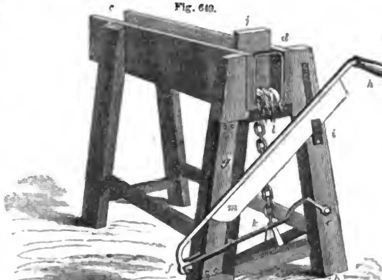
Fig. 648.

HAY-KNIFE.

1728. It will be observed in the figure that the back of the blade is less than a right angle to the handle, a position which gives the cutting edge of the knife an inclination to the line of section, which, when the knife is used up and down in a perpendicular motion with both hands, causes it to cut a longer space than the breadth of the blade. This form of hay-knife requires a considerable degree of strength in its use, and unless the edge is kept remarkably keen with a whetstone, and the hay is firm, it does not make good or quick work.

1729. *Hand Straw or Hay Cutter.*—A simple form of hand straw or hay cutter is illustrated in fig. 649. It may easily be made by a mechanic in the rural districts or in the colonies, as there is an entire absence of all complicated mechanism, all the working parts being of easy construction. The height of the framework is 3 feet, the distance between *a b* being 22 inches; the four uprights are 3 inches by 2 inches, and the length of the trough *c*, in which the straw is to be cut, is 42 inches. The width at the further end *c* is 8 inches, and at the feed end *d* 7½ inches. The length of the knife *m* is 25½ inches, and its breadth 2½ inches. The knife is jointed at its lower extremity to the end *f* of a lever which works on a stud, passed through an eye forged at one end *e*. This lever is made with a slotted or forked end *f*, working up and down on the guide-pace *g*, nailed to the upright *a* in such a way as to admit of a space a little wider than the thickness of one side of the fork of the lever *f*.

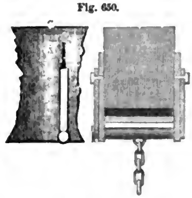
Fig. 649.



HAND STRAW OR HAY CUTTER, IN PERSPECTIVE.

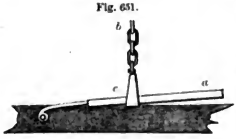
The extremity of the knife is provided with a handle *h*. While not in use, the knife rests on the guard *i*. The hay or straw to be cut is fed through the end of the trough *d*, the length of the cut being regulated by the attendant; and while being cut, it is held in its place by the block *j*, acted on by the pressure of the foot of the attendant on the pedal *k*, through the medium of the chain *l*. The cutting is performed by the operator lifting, in the first instance, the knife by the handle out of the guard *i*, and pushing it towards *d*, so that the edge will be beyond the straw projecting from the feed-mouth. The knife is then lifted upwards, along with the end of the lever *f*, till the end of the knife near *f* is on a level with the straw protruding through the feed-mouth; the end *m* of the knife is then brought down towards the rest or guard *i*, the end *f* of the lever *f e* being at the same time depressed. The double action, first of the knife *m* on its centre *f*, and of the lever *f e* on its centre *e*—the handle of the knife *h*, and the end *f* of the lever *e f*, describing arcs of circles—imparts to the cutting edge the downward and lateral movement essential to a quick and clean cut.

Fig. 650.



FEED-MOUTH OF HAND STRAW-CUTTER.

Fig. 651.



PEDAL OF HAND STRAW-CUTTER.

1730. Further simplification of construction might be attained by dispensing with the lever *f e*, and jointing the end of the knife to the framework; but in this case, by depressing the handle *h*, the edge of the knife would be pressed against the straw, and a tearing rather than a cutting action would be the result. By the arrangement in fig. 649, the knife having a lateral movement towards *f*, and a downward one towards *i*, the razor-like action so well known to produce a clean and rapid cut is attained.

1731. In fig. 650 we give two views of the feed-mouth, *a* being a side, and *b* a front view; and in fig. 651 is a view of the pedal *a*, showing connection of the chain *b* by the stirrup *c*, by which the pressure is produced on the block *j*, fig. 649, the duty of which block is to keep the straw in its place while being cut.

1732. The price of this hand hay and straw cutter may be set down at from 30s. to 40s.

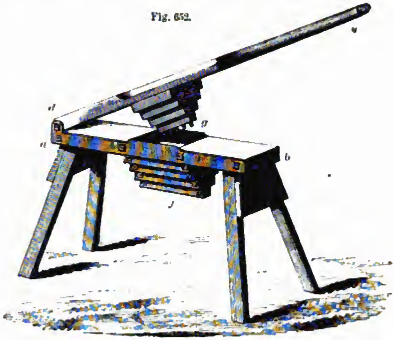
1733. *Hand Lever Turnip-Slicer for Cattle.*—One of the cheapest and most efficient turnip-slicers is represented in fig. 652. It was brought before the Highland and Agricultural Society of Scotland by Mr Wallace of Kirkconnel, as an improvement on a pre-existing machine of the same kind.* It has since undergone some further improvements in the hands of A. and G. H. Slight, Edinburgh; and for the purpose of regular and perfect slicing of turnips, it may be held as the best and cheapest now employed.

1734. In fig. 652 *a b* is the sole of the machine, about 34 inches long, 6 inches broad, and 2 inches thick. The sole *a b* is in two pieces, connected by an iron bar or strap *a c*, which is repeated on the opposite side, and the whole bolted together as in the figure. The two pieces forming the sole are separated longitudinally from each other, so as, with the two side-straps of iron, to form a rectangular opening of 9 inches by 6 inches, bounded on the two ends by parts of the sole, and on the two sides by the side-straps. The sole is supported at

* *Transactions of the Highland and Agricultural Society*, vol. xiv. p. 363.

the height of two feet upon four legs, and the lever *d e* is jointed at *d* by means of a bolt passing through it and the ears of the side-straps, as seen at *d*. The lever *d e* is 4 feet in length, its breadth and thickness equal to that of the sole, but is reduced at the end *e* to a convenient size for the hand.

Fig. 652.

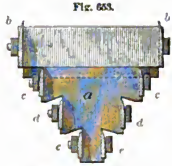


HAND LEVER TURNIP-SLICER FOR CATTLE, IN PERSPECTIVE.

1735. The improvements introduced by the Messrs Slight consist in the application of a cast-iron knife-block *f*, with eight instead of six cutter-knives, which give a more convenient size of slice. This cast-iron knife-block gives greater strength to the machine, and a more steady and secure feature to the interior knives.

1736. Fig. 653 is a section of the cradle as it appears with the cast-iron knife-block: *a* is the body of the block, which is attached to the sole *a b*, fig. 652, through the medium of a flange behind, and fixed by bolts. The external cutters *b b* are a part of the side-straps *a c*, fig. 652, and the interior cutters are fixed in pairs, *c c*, *d d*, *e e*, by their respective bolts passing through the cutters and the block.

Fig. 653.

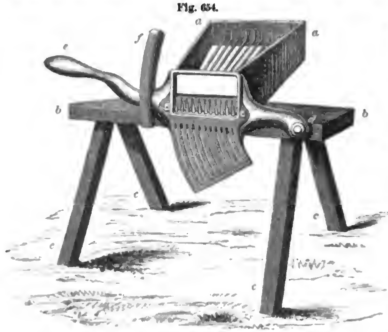


SECTION OF CRADLE.

1737. In using this machine, the workman takes hold of the lever *d e* with the right hand, and, having raised it sufficiently high, he with the left hand throws a turnip into the cradle *f*. The lever is now brought down by the right hand, which, with a moderate impetus, and by means of the block *g*, sends the turnip down upon the cutters, through the openings of which it passes while the cutters are dividing it, and the whole falls away in perfectly uniform slices below, where they may be received in a basket. In most cases, it is found more convenient to have a boy to throw in the turnips, and this will somewhat expedite the work. Two advantages this turnip-slicer possesses, and they are both important—one is, that with unerring certainty it cuts every slice of uniform thickness: the slab-slices, indeed, may of course vary, but all are free of the smallest portion of waste; and the other advantage is its cheapness, especially when it is considered that, in a given time, it will slice weight for weight of turnips with the most elaborate machine in use, the power applied being also equal; and its price is only from 28s. to 30s. The implement is also extremely portable, and can be carried about by one person. An objection has been urged to this slicer—namely, that the turnips must be all put into it one by one; but it is perhaps unnecessary to remark, that this objection applies to all turnip-slicers; for though the hopper of some may be capable of containing a large number of turnips at a time, yet only one turnip is sliced at a time.

1738. *Samuelson's Hand Lever Turnip-Slicer.*—In fig. 654 we give a perspective view of a hand-lever turnip-slicer, adapted for small occupations, where only two or three cows and a few sheep are kept. Different forms of knives are used, according as slices are wanted for cattle, or "fingers" for sheep. This implement is manufactured by Mr Samuelson of Banbury, and costs £1, 15s. The hopper *a a*, fig. 654, 3 feet 3 inches long, 11 inches deep, 3 feet 3 inches broad at its upper, and 18 inches at its lower end, and having a sparred bottom of iron rods to admit earth through them, is fixed to the beam or bar *b b*, 5 feet 4 inches long, 15½ inches broad, and 3½ inches thick. This is carried by four supports *c c*, *c c*, 3 feet 6 inches high, and 5 inches broad by 4 inches thick. The cutting-knife works on the centre *d*, the handle *e* working in the slot of the curved guide *f*.

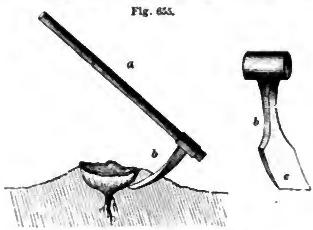
Fig. 654.



SAMUELSON'S HAND-LEVER TURNIP-SLICER, IN PERSPECTIVE.

1739. *Turnip-Picker.*—Until of late years, sheep were allowed to help themselves to turnips, and when the bulbs were scooped out as far as the ground would permit, their *shells*, as their bottoms fast in the ground are called, were picked out with a ***turnip-picker***, the mode of using which may be seen in fig. 655. Its handle *a* is 4 feet long, and blade *b* 10 inches, including the eye for the handle, and its face is brought to a sharp edge of steel *c*. By its mode of action, the tap-root of the turnip is cut through and left in the ground, and the shell separated from the ground, at one stroke.

Fig. 655.



THE BEST FORM OF TURNIP-PICKER IN USE.

Fig. 656.

OBJECTIONABLE FORM OF TURNIP-PICKER.

1740. A common but bad form of these pickers is with the mouth cleft in two, as in fig. 656, which, when picking up the shell, pulls up the tap-root with it. The tap-root, when thus exposed and eaten, is very pungent to the taste, and is apt to engender purging in sheep.

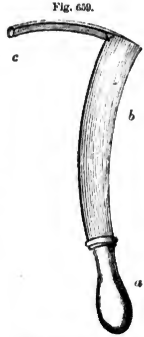
Fig. 657. Fig. 658.

IMPLEMENTS FOR TOPPING AND TAILING TURNIPS

1741. *Topping and Tailing Turnips.*—Figs. 657 and 658 represent the instruments for topping and tailing turnips in their simplest form. Fig. 657 is an old scythe reaping-hook, with the point broken off. This makes a light instrument, and answers the purpose pretty well; but fig. 658 is a better. It is made of the point end of a worn-out patent scythe, the very point being broken off, and part of the iron back to which the blade is riveted, forming a tine, is driven into a helve like that of fig. 657. This instrument is rather heavier than that of fig. 657, on which account it removes the top more easily.

1742. *The Turnip Trimming-Knife.*—A superior instrument was contrived by Mr James Kinninmonth, at Inverteil in Fife, under the name of the "turnip trimming-knife," fig. 659. The necessity for another instrument of the kind arises from the fact, that when the top of a turnip has dwindled into a comparatively small size, it affords but an inadequate hold for pulling the turnip from the ground; and when the attempt is felt by the worker likely to fail, she naturally strikes the point of the instrument into the bulb to assist her, and the consequence is, that a deep gash is made in the turnip, which, being stored for months, generally suffers in its useful qualities, by producing premature decay in the wounded part. In fig. 659, *a* is the handle, *b* the cutting edge, steeled and properly tempered, and *c* an appendage welded to the extremity of the back, in the form of a narrow edge or hoe. If the turnip requires any effort to draw it, the front of the hoe *c* is inserted by the right hand gently *under* the bulb, and the operation of lifting it with the left hand by the top of the turnip such as it is, is effected with the greatest ease and certainty.

Fig. 659.



TURNIP TRIMMING-KNIFE.

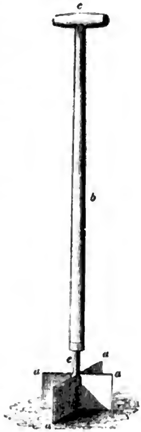
1743. The price of this knife, when made on purpose, is 1s. 6d., but were it brought out as a regular article of manufacture, its price might be considerably less.*

1744. *Cross Turnip-Chopper.*—There is another very simple and useful turnip-cutter, which is frequently used when thin slicing is thought of less importance, but is more especially useful where the cooking system is adopted for either cows or horses, thin slicing being in such cases not called for. This instrument is represented in fig. 660. The cutting part of it consists of 2 steel-edged blades, 8 inches in length, and 4 inches in depth. They are slit half-and-half at their middle point, so as to penetrate each other, standing at right angles, forming the *cross-cutter*, *a a a a*. They are then embraced in a four-split palm, and riveted. The palm terminates in a short shank *e*, which is again inserted into the hooped end of a wooden handle *b*, 3 feet in length, and this is finished with a cross-head *c*. The price of this instrument is 8s. 6d. The mode of using it is obvious. It is held by the hand in a vertical position; and when placed upon a turnip, one thrust downward cuts it in quarters.

1745. This instrument is also varied in its construction, being sometimes made with three and even with four blades, dividing the turnip into six or into eight portions.

1746. *Parallel-bladed Turnip-Chopper.* — Another individual form of the same species is represented by fig. 661. It has two blades *a a*; but they, instead of crossing, stand parallel to each other, and therefore divide the turnips into three portions, resembling slices, of considerable thickness, the middle one being 1½ inch thick. In the construction

Fig. 660.



THE CROSS TURNIP-CHOPPER.

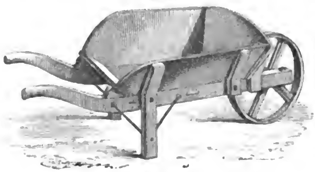
* *Transactions of the Highland and Agricultural Society* for July 1844, p. 286.

of this cutter, a blunted stud is formed at the extremities of each blade, and these project below the cutting edge about ¼ inch, serving as guards to save the cutting edges from receiving injury when they have passed through the turnip, or otherwise striking any hard surface. These guards, it may be remarked, would form a useful addition to all this class of cutters. The arms *b* of the blades rise to a height of 9 inches, widening upwards to 3½ inches, to give freedom to the middle slice to fall out. The two arms coalesce above, and are then formed into the socket *c*, to receive the handle, which terminates in a cross-head.

Fig. 661.

TURNIP-SLICER WITH PARALLEL BLADES.

Fig. 662.



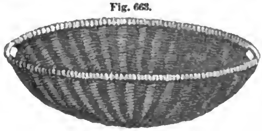
WHEEL-BARROW

1747. *Common Wheel-Barrow.*—In cleaning out byres and stables, a wheel-barrow, as in fig. 662, is necessary. This is of the common form, with close-boarded bottom, sides, and back, and of a capacity sufficient to carry a good load of litter, but not of greater breadth than will easily pass with a load through an ordinary door.

1748. The broad-mouthed shovel, fig. 411, is also necessary for cleaning out byres and stables.

1749. *Scull-Basket.*—Turnips are carried to the cows in baskets called *sculls*, which are hollow hemispherical-shaped baskets of basket-willow, having an opening on each side, to take hold of the stout rim for handles, such as in fig. 663: they are 2 feet in diameter, and cost about 1s. 6d.

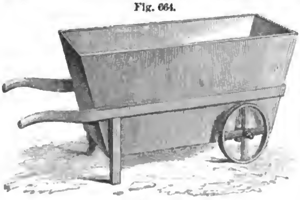
Fig. 663.



WILLOW SCULL OR BASKET

1750. *The Cooler.*—After the cattle-food is prepared in the boiling apparatus of the dairy, it is taken to the byre in a cooler. This is an oblong box, fig. 664, having the sides perpendicular, and the ends bevelled, and provided with two wheels, mounted on a bent axle, which passes under the bottom of the box, and two handles, for the purpose of moving the cooler to where it is wanted. The cooler may be constructed of any dimensions, to suit the size of the dairy; and one 6 feet long, 2 feet wide, 2½ feet deep, will contain as much food as will serve twenty cows at one meal.

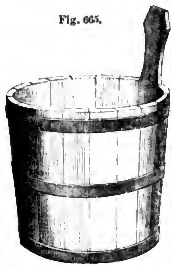
Fig. 664.



COOLER FOR A BYRE.

1751. *The Milk-Pail.*—The vessel for receiving the milk from the cow is simple, and is shown in fig. 665, which represents one of the most convenient form, and the size may be made to suit the dairymaid's taste. It is made of thin oak staves bound together with three thin iron hoops, which should always be kept bright. Pitchers of tin are mostly used to milk in in the dairies of towns. A pail, as fig. 665, is of a convenient size when 9 inches in diameter at the bottom, 11 inches at the top, and 10 inches deep, with a handle 5 inches high, and having a capacious enough mouth to receive the milk as it descends, and of a sufficient height to rest on the edge of its bottom when held firmly between the knees of the dairymaid, as she sits in milking upon a three-legged stool. As the pail should not be milked full, it should be large enough to contain all the milk a cow will give at a milking, since it is undesirable to disturb the cow by rising from her before the milking is finished, or by exchanging one pail for another.

Fig. 665.



MILK-PAIL.

Fig. 666.

MILKING-STOOL.

1752. *The Milking-Stool.*—The byre-stool, seen in fig. 666, is made of ash, to stand 9 inches in height, or any other height to suit the convenience of the dairymaid, with the top 9 inches in diameter, having a segment cut off one side, and the legs a little spread out below to give the stool stability. Some milkers do not care to have the assistance of a stool in milking, and prefer sitting on their haunches; but a stool keeps the body so steady and secure, that the arms have greater freedom of action, and are more ready to prevent accidents to the milk in case of any dispute with the cow.

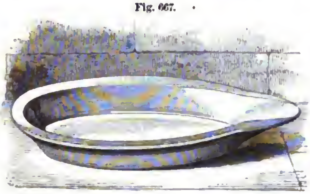
1753. *Milk-Dishes.*—Milk-dishes are composed of stoneware, glass, wood, metal, and stone. The stoneware consists of common ware and Wedgewood; the wooden of cooper-work; the metal of block-tin and of zinc; the stone of slate, pavement, and marble polished. Besides these simple elements, a combination of materials is used, as, wooden vessels lined with block-tin and zinc, and German cast-iron lined with porcelain. Of all these, the stone and wooden ones lined with metal are stationary, and the others movable. Wooden ones require much labour to keep them thoroughly clean, but are the least liable to be injured in the use. Metal ones also require much cleansing, and are liable to be bruised. Stoneware is easily fractured, though very easily cleaned. Glass is as easily cleaned, and perhaps more frangible. The form of all milk-dishes should be broad and shallow, for the purpose of exposing a large surface with a small depth of milk, to facilitate the disengagement of the cream from the milk.

1754. A difference in opinion exists, which substance as a milk-dish has the greatest influence in disengaging the largest quantity of cream from the milk.

1755. *Common Stoneware Milk-Dish.*—These milk-dishes are brown outside, and glazed yellow inside, of round form, tapering to the bottom, and without a mouth to pour the milk by. When 15 inches in diameter, and 4 inches deep, inside measure, they cost 9d. each. They are easily cleaned and broken, and the glazing is not durable.

1756. *Wedgewood-ware Milk-Dish.*—Fig. 667 represents a milk-dish of white Wedgewood-ware, of an oval form, 16 inches long and 3 inches deep, inside measure, with a mouth. This ware is hard, not easily broken, the glazing durable, and easily cleaned. A dish of this size costs 6s. Wedgewood or white ware is also made of the form of the wooden one of cooper-work, fig. 669, with the addition of two handles to lift the vessel by.

Fig. 667.

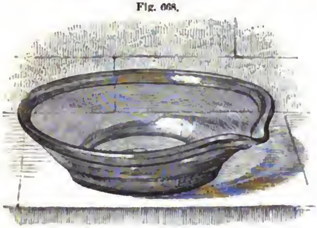


WEDGEWOOD-WARE MILK-DISH.

1757. *Glass Milk-Dish.*—A milk-dish made of light-green coloured glass, of a circular form, 16 inches in diameter and 4 inches deep, tapering to the bottom, and with a mouth, is seen in fig. 668. It is easily cleaned, and easily broken if carelessly handled. The cost of a dish of this size is 4s. 6d.

1758. *Wooden Milk-Dish.*—Fig. 669 is the common wooden milk-dish, made of round cooper-work, composed of staves of oak and flat hoops of iron. It is

Fig. 668.



GREEN GLASS MILK DISH.

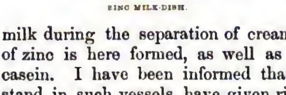
Fig. 669.

WOODEN MILK-DISH

16 inches in diameter, and 4 inches deep, inside measure, and costs 2s. This is the most durable of all milk-dishes, although it requires much scrubbing when in use to keep it clean, and the iron hoops bright, which they should always be.

1759. Fig. 670 exhibits a milk-dish made of zinc, of a circular form, 18 inches in diameter, and 3 inches deep, provided with a mouth, and costs, of this size, 2s.—the price varying 3d., more or less, for every inch in the diameter. Zinc requires much cleansing, and is apt to be bruised, though not easily broken.

Fig. 670.



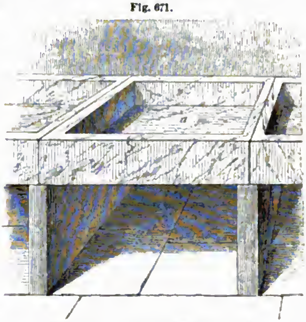
ZINC MILK-DISH.

1760. Dr Taylor has these observations in regard to the use of vessels made of zinc for dairy purposes: "Zinc has been lately used in making utensils for holding milk during the separation of cream. It is probable that some of the lactate of zinc is here formed, as well as a combination of the oxide of zinc with casein. I have been informed that milk and cream, which were allowed to stand in such vessels, have given rise to nausea and vomiting. This practice would not be allowed under a proper system of medical police. When an *acid* liquid has been placed in a zinc vessel, there is a strong chemical action, and the liquid becomes invariably impregnated with a salt of zinc. A cider-merchant kept for three months a quantity of cider in vessels made of zinc. It was observed that the liquid had then acquired an acrid and styptic taste. On analysis, it was found to contain a large quantity of acetate of zinc. It had, therefore, become decidedly poisonous."* Milk kept in zinc vessels until it becomes sour, would, we have no doubt, produce a similar poison. When milk is so delicate a fluid, and so easily affected by any deleterious substance, great caution is requisite in using any metallic vessel in the dairy that might possibly injure its quality.

1761. Tin is not known to be acted on by milk.

1762. *Fixed Milk-Cooler of Marble.*—A fixed milk-cooler is represented by fig. 671, made of marble, the best material for a cooler, being cool, cleanly, and handsome. An orifice is made in the bottom *a*, at the near side, through which the milk runs out of the cooler, and where also the water issues which has been used to wash the cooler clean. The dimensions may be made at pleasure, 3 feet long and 2 feet broad being a good size; but the depth should not exceed 4 inches, to contain from 2 to 3 inches of milk.

Fig. 671.



A FIXED MILK-COOLER OF MARBLE, OR OF WOOD LINED WITH METAL.

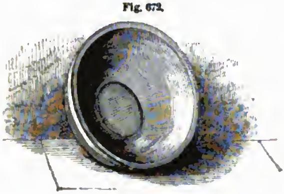
1763. When the cooler is made of wood lined with block-tin or tin, the form is the same as the marble one.

1764. It is only in large dairies that fixed coolers are used.

1765. *The Milk-Sieve.*—Another utensil required for the use of the milk is a milk-sieve, fig. 672, which consists of a bowl of wood formed of plane-tree, having an orifice in the bottom, which is filled in with gauze, in order to detain the hairs that may have fallen into the milking-pails from the cows on being milked. The gauze is commonly made of brass-wire, and, when kept bright, answers the purpose; but silver wire is much less likely to become corroded by use. Such a sieve, 9 inches in diameter, with brass-wire gauze, costs 1s. 3d.

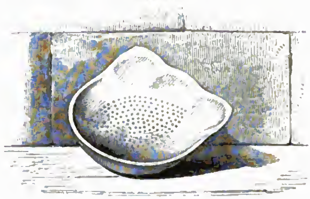
1766. *The Creaming-Dish.*—The creaming-dish, fig. 673, made of china, and

Fig. 672.



MILK-SIEVE.

Fig. 673.



CREAM SKIMMER.

sometimes called the skimmer or creamer, is for taking the cream off the milk. It is thin, circular, broad, and shallow, having on one side a sharp edge to pass easily between the cream and the milk. At the bottom are a number of small

* TAYLOR *On Poisons.*

holes to allow the milk to pass through and leave the cream pure and thick in the skimmer. Such a skimmer costs 1s.

1767. *Cream-Jar.*—The cream, until it is churned, is kept in a jar of stoneware, as in fig. 674, about 18 inches in height, and 10 inches in diameter, provided with a movable top, having an opening in its centre, covered with muslin to keep out dust and let in air. Such a jar costs 8s. to 10s. of white ware; of common ware cheaper.

Fig. 674.

CREAM-JAR.

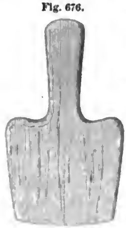
1768. *Butter Moulds.*—Fig. 675 represents a stamp $1\frac{1}{2}$ inch diameter, for small prints of butter used at table; the design upon which is cut in accordance with fancy and taste. The couple of hands, ribbed on their faces with longitudinal parallel ridged lines, are for forming small figured balls and rolls of butter, also for the table. The hands are 6 inches long, and 4 inches broad in the face, and 4 inches long in the handles.

Fig. 675.

BUTTER PRINT-MOULD AND HANDS.

1769. *The Butter-Spade.*—Objections have been urged against the use of the human hand in making up butter, and a small wooden spade recommended to be employed instead. The use of water has also been objected to, as it is said to deprive the butter of its pleasing aroma. A woman who has hot clammy hands should never be a dairymaid, as butter is very susceptible of taint, and its flavour will doubtless be injured by the heavy smell of sweaty hands; but *naturally* cool hands—made clean by washing in warm water and oatmeal, *not soap*, and then rinsed and steeped in cold water, will make up butter freer of buttermilk, and more solid than any instrument whether of wood or other material. As to cold water injuring butter, it is scarcely possible, there being no affinity between fatty matter and cold water; water cannot dissolve any essential ingredient out of butter; at any rate, water will more effectually unite with, and thereby take away the milky substance from butter, than any instrument manipulated dryly with all the art the hand can use. But less handling may be given to butter with the partial use of the spade, which may be employed in the first process of the washing, by dividing and rubbing, and rolling it amongst the water on the bottom of a flat tub, before it is beaten with the hands; and it is this beating which expels the remnants of the buttermilk which cannot be farther reached by the water, and which, if left, would spoil the taste of the butter in a very few days, that is best done by the hand. Fig. 676 represents a butter-spade of a shape long used in a dairy, the face being 4 inches square, and the handle 4 inches long. The lower side of the face is thinned away to a sharp edge. That such a spade may last in use, and not warp, being thin, it should be made of hardwood, and the wood of the apple-tree is found to be the most tenacious.

Fig. 676.

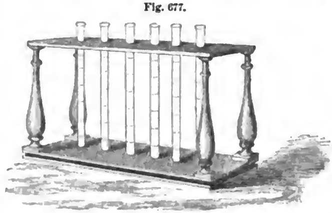


BUTTER-SPADE.

1770. The Dutch use an implement for washing butter without the immediate contact of the hand, which is much more effective than this spade. It consists of a board of wood about 1 foot in length and 4 inches in breadth, deeply grooved longitudinally. Another board, of similar construction and dimensions, is hinged upon one end of it, and terminates in a handle. The instrument is placed in a flat kit, with water. While the butter is placed by one hand at quick intervals of time, with such a spade as fig. 676, upon the lower board, the other hand moves the upper board up and down in repeated action upon the butter, which is alternately and successively divided by the grooves meeting into one another, and kneaded thin by the frequent contact of the grooves of the boards. By repeated operations in this manner the butter is considered to be freed entirely of the buttermilk. Still the most expert manager of this process cannot free the butter of buttermilk so completely as can the manipulator by a pair of cool active hands.

1771. *A Lactometer.*—A lactometer, to test the creaming qualities of milk drawn from different cows, is useful in dairies. It consists of a frame, fig. 677, containing a series of glass tubes of equal length and diameter. These are graduated as shown in the figure, and are filled to an equal height with milk from different cows, when, after remaining some time quiescent, the stratum of cream is easily marked off in each.

Fig. 677.



LACTOMETER IN PERSPECTIVE

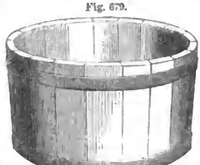
1772. *The Curd-Cutter.*—When milk is sufficiently coagulated, the curd is cut in the tub with the curd-cutter, fig. 678, which consists of an oval hoop of copper *a b*, 9 inches long and 6 inches wide, and 1½ inch deep, embracing a slip of copper, of the same depth, along its longitudinal axis. The stem *c*, of round copper rod, is branched and stemmed, and is 18 inches in height, surmounted by a wooden handle *d*, 6 inches in length. On the instrument being used in a perpendicular direction, it cuts the curd in the tub into pieces.

Fig. 678.

CURD-CUTTER

1773. *The Cheese-Vat.*—Fig. 679 shows the common cheese-vat or *chessart*, as it is called, the form being varied according to that adapted to the cheese. This vat is built with elm staves, as being least liable to burst with pressure, and strongly hooped, and is furnished with a substantial bottom, pierced with holes to allow the whey expressed to flow away, and a strong wooden cover cross doubled. It is of advantage that the cover fit the vat exactly, and that the vat have as little taper interiorly as possible. In some parts, as in Cheshire, cheese-vats are made of tin, with holes in the bottom.

Fig. 679.



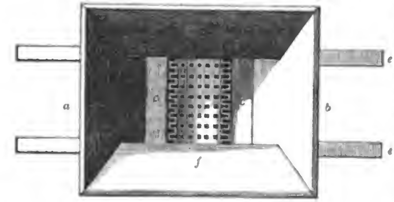
CHEESE-VAT.

1774. *The Curd-Breaker.*—The curd-breaker,* of which fig. 680 is a plan, and fig. 681 a transverse section, consists of a hopper-shaped vessel *a b*, 17 by 14

* *Quarterly Journal of Agriculture*, vol. iv. p. 384.

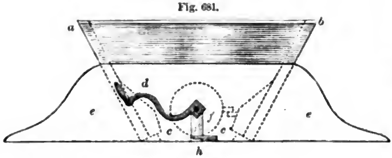
inches at top, and 10 inches deep. It is fixed upon two bearers *e e*, which are set upon a stand or tub when in operation. A wooden cylinder *f*, having an iron axle passing through the bearers *e e*, is turned by a winch-handle *d*. The axle is kept in its bearings by means of slots *h* on each side, which slide in grooves in the bearers, and are held in their place by a slider at *h*. The cylinder *f* is 7 inches long and $3\frac{1}{2}$ inches diameter, studded all over with pegs of hardwood $\frac{1}{4}$ inch square, and projecting $\frac{3}{8}$ inch. These pegs or teeth are set in eight regular zones round the cylinder, each zone containing eighteen teeth. Two wedge-shaped pieces *c c* are attached to the sides of the hopper below, serving at the same time to reduce the opening between the cylinder and the hopper, and to carry a row of pegs similar to those of the cylinder, but falling into the spaces between the zones of pegs, as seen in fig. 680 at *c* and *c*.

Fig. 680.



CURD-BREAKER.

Fig. 681.



SECTION OF THE CURD-BREAKER.

1775. In using this machine, it is placed over the tub or other recipient for the broken curd; the hopper is filled with the curd that requires to be broken; and while one hand is turning the winch-handle, which may be turned either way, the other hand may occasionally be required to press the curd down upon the cylinder. To prevent the curd passing beyond the ends of the cylinder, the cylinder is covered at each end, to the extent of $\frac{1}{2}$ inch, with an overlap of the sides of the hopper. The cost of this curd-breaker is 8s.

1776. *The Dung-Spade.*—The litter in the courts of hammels is much more compressed than that in large courts, as a consequence of heavy cattle standing and moving over it frequently within a limited space. It is sometimes so compressed as almost to resist the entrance of the graip. To enable it to be easily lifted with the graip, it should be cut into parallel daces with the dung-spade, fig. 682. This spade consists of a heart-shaped blade of steel thinned to a sharp edge along both sides and pointed, with a stout short helve having a long cross-head fastened into a split socket. The height of the spade is 3 feet, length of cross-head 18 inches, length of helve 18 inches, length of blade 16 inches and breadth 10 inches. It is kept sharp with a scythe-stone.

Fig. 682.

DUNG-SPADE.

1777. In using this spade, it is lifted up with both hands by the cross-head, and its point thrust with force into the dung-heap along a line across its entire breadth. The upper part of the blade of this spade, it will be observed, is rounded, and not left square with ears like a common spade, because when used to cut a dung-heap of greater depth than the length of its blade, the rounded part does not catch the litter on the instrument being pulled up out of it.

1778. *The Common Graip.*—The common graip is used for lifting all dry strawy materials. It is used to throw the dung heap into the cart after it has been cut and prepared by the dung-spade. It consists of three rounded sharp prongs, about 12 inches long, forged together, and to which is attached a slightly curved forward shanked socket, into which the helve is fastened, and furnished with a cross-head, as in fig. 683.

1779. *The Three-pronged Dung-Graip.*—Fig. 684 represents a light useful small implement for spreading dung along drills, or minutely broadcast. It consists of three short sharp prongs, welded together and to a socket, into which a helve about 4 feet long, without a cross-head, is fastened. This implement is generally used by women-workers.

Fig. 683.

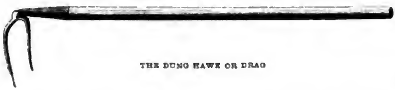
THE GRAIP.

Fig. 684.

THE THREE-PRONGED DUNG-GRAIP.

1780. *The Dung-Drag.*—This implement is sometimes called the *dung-hawk.* It consists of two or three short sharp prongs, forged together, with a socket at right angles to the prongs, furnished with a helve about 5 feet in length, without a cross-head, as in fig. 685. It is used for dragging the dung out of the tilt-cart into heaps along drills, or upon the plain surface.

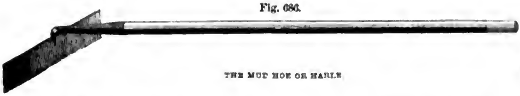
Fig. 685.



THE DUNG HAWK OR DRAG

1781. *The Mud Hoe or Harle.*—The harle consists of a thin blade of iron, about 15 inches in length and 4 inches broad, attached to a socket at right angles to the blade, and furnished with a helve 6 feet in length, without a cross-head, as in fig. 686. Its use is to scrape together and collect all the wet mud to be found on the roads and alleys around the steading in wet weather in winter.

Fig. 686.



THE MUD HOE OR HARLE

1782. SECTION ELEVENTH.—*Machines not directly connected with any of the above Ten Sections, but useful on the Farm.*

1783. *The Lantern.*—A proper form of lantern that will distribute a sufficient intensity of light all around, and be safe to carry to any part of a steading, amongst straw or other highly inflammable material, is yet, perhaps, a desideratum. The nearest approach to safety in those circumstances of any form of lantern we have seen is that in fig. 687, which consists chiefly of a stout glass globe, which may be knocked against a piece of timber and yet not be fractured. It has an oil-lamp, which screws and unscrews into its place from below, within the foot upon which it

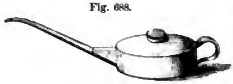
Fig. 687

A SAFE LANTERN

stands, and a ring by which it is carried; and the hand is elevated enough to be protected from the heat which escapes along with the smoke from the ventilator. A lantern of tin, with a globe about 9 inches diameter, a suitable size, costs 6s. 6d.

1784. *The Oil-Can.*—The form of oil-can given in fig. 688 is a convenient one for use in oiling the gudgeons belonging to the thrashing - machine, or the bearings of the spindles of the smaller machines. It consists of a body of tin of the ellipsoidal form, having a handle at one end, and a long spout of small bore at the opposite one; and the mouth on the top is stopped with a lid.

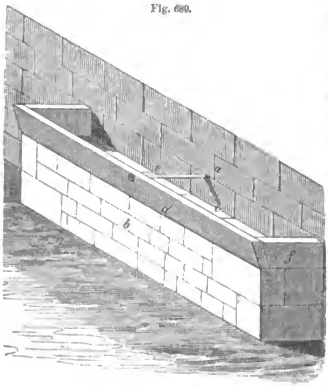
Fig. 688.



THE OIL-CAN.

1785. *Turnip-Troughs for Courts.*—These are placed against the walls, as in fig. 689, where *a* is the wall against which the trough is built, and *b* a building of stone and lime 2 feet thick, to support the bottom of the trough, of which the lime need not be used for more than 9 inches in the front and sides of the wall, and the remaining 15 inches may be filled up with any hard material: *c* is the flagging placed on the top of this wall, to form the bottom of the trough. Some board the bottom with wood; and where wood is plentiful, it is cheap, and answers the purpose, and is pleasanter for the cattle in wet and frosty weather; but where flags can be easily procured, they are more durable: *d* is a plank 3 inches thick and 9 inches in depth, to keep in the turnips. Oak-planking from wrecks, and old spruce-trees, however knotty, have been found a cheap and durable front for turnip-troughs. The planks are spliced together at their ends, and held on edge by rods of iron *e* batted with lead into the wall, and with nut and screw in front. The height in front should not exceed 2 feet 9 inches for calves, and 3 feet for the other beasts, and it will become less as the straw daily accumulates. The trough, here shown short, may extend to any length along the side of a court.

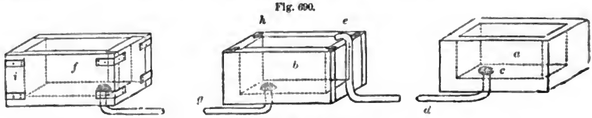
Fig. 689.



TURNIP-TROUGH FOR COURTS.

1786. *Water-Troughs for Cattle.*—Fig. 690 gives an arrangement of water-troughs connected together though placed in different courts. Let *a* be the supply-

Fig. 690.



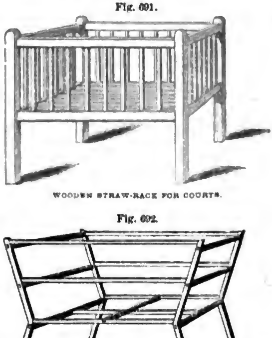
WATER-TROUGHS FOR CATTLE.

trough in one court immediately beside the pump; let *b* be the trough in any other court to be supplied with water from *a*, and let *b* be placed 3 inches below *a*. Let a lead-pipe *d* be passed under ground to the trough *b*, and emerge from the ground by the side of and over the top of *b* at *e*. When *a* is filling with water from the pump, the moment the water rises in *a* to the level of the end of the pipe at *e*, it will begin to flow into *b*, and will continue to do so till *b* is filled if the pumping is continued. The water in *a*, *below* the level of the end of the pipe *e*, may be used in *a* without affecting that in *b*, and the water in *b* may be entirely used without affecting that in *a*. In like manner water may be supplied to *f* from *b*.

1787. Water-troughs are made of various materials: *a* is hewn out of a solid block of sandstone, which makes the closest, most durable, and best trough; *b* is made of flagstone, the side being sunk into the bottom in grooves luted with white-lead, and held together at the corners by iron clamps *h*. This makes a good trough, but it is apt to leak at the joints: *f* is made of wood dovetailed at the corners, and held together by clamps of iron *i*. When made of good timber, and kept painted, wooden troughs last many years.

1788. *Wooden Straw-Rack.*— A common kind of rack is in fig. 691, made of wood, 5 feet square and 4 feet high, sparred round the sides and bottom to keep in the straw. It stands in the middle of a court. The cattle draw the straw through the spars as long as its top is too high for them to reach over it, but after the dung accumulates, and the rack thereby becomes low, the cattle get at the straw over the top. This rack may be pulled up higher when the dung accumulates much.

Fig. 691.



WOODEN STRAW-RACK FOR COURTS.

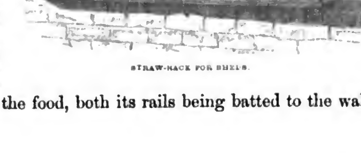
1789. *Iron Straw-Rack.*—Fig. 692 is a rack of malleable iron to supply the straw always over its top, and is rodded in the sides to keep in the straw. It remains constantly on the ground, and is not drawn up as the dung accumulates, as in the case of the wooden rack. It is $5\frac{1}{2}$ feet in length, $4\frac{1}{2}$ in breadth, and $4\frac{1}{2}$ in height; the upper rails and legs are of 1-inch-square iron, and the other rails $\frac{3}{4}$ inch. This is, of course, the most durable straw-rack.

Fig. 692.

IRON STRAW-RACK FOR COURTS.

1790. *Straw-Rack for Sheds.*—Figs. 691 and 692 represent straw-racks to be constantly exposed in the air; fig. 693 is a form of wooden rack adapted to supply fodder to cattle under cover in sheds. It consists of an upper and a lower bar of wood, parallel to each other, and into which are notched behind a series of rails as far asunder as to allow of the straw being pulled through between them by the cattle. The rack has an inclination of about 2 feet forward at the top, which affords the capacity of holding the food, both its rails being batted to the wall.

Fig. 693.



STRAW-RACK FOR SHEDS.

1791. *The Bullock Holder.*—The bullock-holder is well represented by fig. 694, where a is the joint which allows its two parts at b to open so far as each to enter a nostril of the animal. The lever-nut c brings the two knobbed points b as close as to embrace and hold firm the septum of the nose. The leading rein is fastened to the under ring e. This form of bullock-holder would allow the points b to be screwed to any degree of tightness, until they meet each other; and it is, in our opinion, so far objectionable, as the screwing may be carried as far by a rash hand as to hurt the animal when the instrument was moved in the least degree to either side.

Fig. 694.

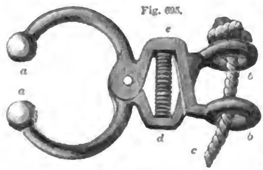
THE BULLOCK-HOLDER.

1792. Another form which we have seen, and approve of, never allows the two knobs b of the instrument to be screwed closer than just to embrace the septum of the nose, allowing the holder to swing from the nose at ease whilst it grasps the nose firmly whenever the animal attempts to move away.

1793. The cost of a bullock-holder of either of these forms is 4s.

1794. *American Cattle-Leader.*—In fig. 695 we give a view of an American cattle-leader, which presents some points of novelty. The septum is pressed on by the balls a a. The thumb and finger are pressed over the parts b b, or immediately over the spring e d; the distance between the balls a is thus widened, and the apparatus is then slipped upon the septum, and the spring gently closes it; c being the rope or leading rein.

Fig. 695.



AMERICAN CATTLE-HOLDER.

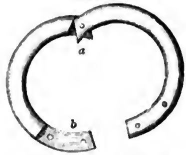
Fig. 696.

SWIVELLED SPRING-HOOK

1795. *Spring-Hook Swivel.*—The leading-rein is best fastened to a ring or holder by means of a spring-hook swivel, such as fig. 696. The movable part a is jointed at d, and kept in its place by the spring behind it. When the hook is desired to be attached to the ring, the thumb presses on a, which yields, and allows the ring to be taken into the circular void of the hook. The rein-rope b is spliced on the end of the ring of the hook. This ring, turning upon the swivel c, prevents the rope twisting. With such a hook a leading-rope can be attached and released from the bull's ring in much less time and with more ease than any sort of tying.

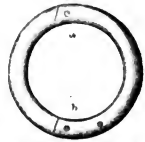
1796. *The Bull's Ring.*—In fig. 697 is given a view of a bull's

Fig. 697.



THE BULL'S RING IN A STATE TO BE INSERTED INTO THE BULL'S NOSE

Fig. 698.



THE BULL'S RING AS FASTENED IN THE BULL'S NOSE.

ring in an open state, ready to be inserted into the bull's nose, the joint a allowing the two sides of the ring to open as wide as that the end b may be inserted into the hole burned through the septum of the nose. Fig. 698 shows the ring closed, after it has been passed into the nose, *a* being the joint, and *b* the two ends of the ring lapped over and secured together by two counter-sunk screws. The ring is formed of ¼ inch of rod-iron, and its diameter over all is 2½ inches, and it should be highly finished.

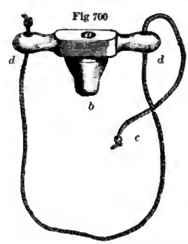
1797. *The Cattle Probang.*—When cattle are feeding on turnips or potatoes, it occasionally happens that a piece larger than will enter the gullet easily is attempted to be swallowed, and obstructed in its passage. The accident chiefly occurs to cattle receiving a limited supply of turnips, and young beasts are more subject to it than old. When a number of young beasts in the same court only get a specified quantity of turnips or potatoes once or twice a-day, each becomes apprehensive, when the food is distributed, that it will not get its own share, and therefore eats what it can with much apparent greediness, and, not taking sufficient time to masticate, swallows its food hastily. A large piece of turnip, or a small potato, thus easily escapes beyond the power of the tongue, and, assisted as it is by the saliva, is sent to the top of the gullet, where it remains. In cases of this kind, the common probang is used, the cup-end being employed.

Fig. 699

THE CATTLE PROBANG.

1798. The common *probang* is represented in fig. 699, *a* being the cup-end, which is so formed that it may partially lay hold of the piece of turnip or potato, and not slip between it and the gullet, to the risk of rupturing the integument; and being of larger diameter than the usual state of the gullet, on being pressed forward it distends the gullet, and makes room for the obstructing body to proceed to the stomach. Formerly the probang was covered with twisted cane, but is now with India-rubber, which is more pliable. It is used in this manner: Let the piece of wood, fig. 700, be placed into the open mouth of the animal as a bit, the projecting part *b* lying upon the tongue; *c* is the cord attached to it, and to be tied tightly over the neck behind the horns, to keep the bit steady in its place. The use of the bit is not only to keep the mouth open without trouble, but to prevent the animal injuring the probang with its teeth, and it offers the most direct passage for the probang towards the throat by the opening *a*. Let a few men seize the animal on both sides by the horns or otherways, and let its mouth be held projecting forward in an easy position, but no fingers introduced into the nostrils to obstruct the breathing of the animal, nor the tongue forcibly pulled out of the side of the mouth. Introduce now the cup-end *a* of the probang, fig. 699, through the round hole *a b* of the mouth-piece, fig. 700, and push it gently towards the throat until the obstructing piece of the turnip is felt; push then with a firm and persevering hand, cautioning the men, previous to the push, to hold on firmly—for the starting of the piece of turnip by the instrument may cause the animal smart pain, and to wince and even leap aside. The obstruction will now most likely give way, especially if the operation has been performed before the parts around it began to swell; but if not, the probang must be used with still more force, whilst another person rubs with his hands up and down upon the distended throat of the animal. If these attempts fail, a veterinary surgeon should be sent for instantly.

Fig 700



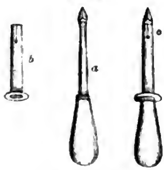
THE MOUTH-PIECE FOR THE CATTLE PROBANG.

1799. The probang, fig. 699, is 5 feet 1 inch in length, $\frac{3}{4}$ of an inch in diameter, with pewter cup, and a ball-end $1\frac{1}{2}$ inch diameter, pierced with holes to allow gas to escape from the stomach. The mouth-piece *a b*, fig. 700, is 5 inches long and 3 inches wide, with two rounded projections *d d*, 4 inches long each. The price of the probang is 12s., and with the mouth-piece 14s.

1800. *Cattle Hoven.*—The direct cause of the symptoms of cattle hoven is undue accumulation of gases in the paunch or large stomach, which, not finding a ready vent, causes great pain and uneasiness to the animal, and, if not removed in time, rupture of the paunch and death ensue. Placing an instrument, such as in fig. 700, across the mouth, to keep it open, is an American cure which is said never to have failed. But the gas may be generated so rapidly that neither medicines nor the probang may be able to prevent or convey it away, in which case the apparently desperate remedy of *paunching* must be had recourse to. "The place for puncturing the paunch," directs Professor Dick, "is on the left side, in the central point between the lateral processes of the lumbar vertebra, the spine of the ileum, and the last rib. Here the *trochar* may be introduced without fear."

1801. *The Cattle Trochar.*—The trochar is represented in fig. 701. It consists of a round rod of iron *a*, 5 inches in length, terminating at one end in a triangular pyramidal-shaped point, and furnished with a wooden handle at the other. The trochar is sheathed in a cylindrical cover or case *b*, called the canula, one end of which permits the point of the trochar to project, and the other end is furnished with a broad circular flange. The canula is kept tight on the trochar by means of a slit at its free end, and the point being somewhat larger in diameter than its own body, expands the slitted end of the canula until the point projects, when the slit collapses to its ordinary state, and the canula is kept secure behind the enlarged point, as at *c*. On using the trochar, in the state as seen at *c*, it is forced with a thrust into the place pointed out in par. 1800, through the skin into the paunch; and on withdrawing the trochar by its handle—which is easily done, notwithstanding the contrivance to keep it on—the canula is left in the opening, and retained in its place by the flange, to permit the gas to escape through the canula. On account of the distended state of the skin, the trochar may rebound from the thrust; and in such an event, a considerable force must be used to penetrate the skin. The spear of the trochar is 5 inches long, and the handle 4 inches; and price, 3s. 6d.

Fig. 701



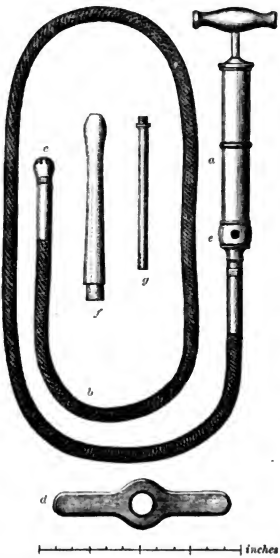
THE TROCHAR.

1802. *Read's Stomach-Pump.*—The instrument represented in fig. 702 is on a scale of $\frac{1}{8}$ of full size. It consists of a sucking and forcing pump *a*, the body being about $1\frac{1}{2}$ inch diameter and 13 inches long over the nozzle or valve-chamber. A flexible tube *b* 7 feet long, with brass ends, is screwed to the nozzle, and at the extreme end has attached a small rose or bulb *c* pierced with holes. When the tube is passed into the stomach, it passes through a wooden mouthpiece *d*, put into the mouth of the animal to prevent the tube being injured. The fluid drawn from the stomach is ejected from the pump by a hole at the side of the handle above the upper valve.

1803. When the pump is to be used for giving injections, the flexible tube *b* is screwed to the hole in the side of the barrel, the rose *c* removed from the end, and a wooden end *f* 10 inches long put on instead, while on the end of the pump *e* is screwed a brass tube *g* $8\frac{1}{2}$ inches long: the end of this tube is closed, but a number of holes are pierced in the side to form a rose. In this state the pump is similar to an ordinary enema syringe, and is used in the same way.

1804. The price of Read's stomach-pump, complete in a case, is £2, 10s.

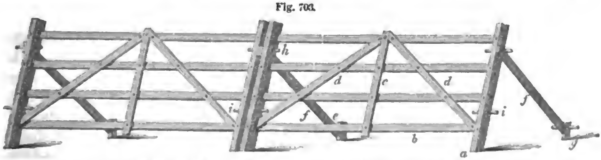
Fig. 702.



READ'S STOMACH-PUMP.

1805. *Wooden Hurdles for Sheep.*—Fig. 703 represents two hurdles or flakes set as they should be. The mode of setting them is this, but in doing it the shepherd requires the assistance of another person: The flakes are set down with the lower ends of their posts in the line of the intended fence. The first flake is then raised up by its upper rail, and the ends of the post are sunk a little into the ground with a spade, to give them a firm hold. The second flake is then raised up and let into the ground in the same way, both being held in that position by the assistant. One end of a stay *f* is then placed between the flakes near the tops of their posts, and these and the stay are made fast together by the insertion, through the holes in them, of the peg *h*. The peg *i* is then inserted through near the bottom of the same posts. The flakes are then inclined backwards away from the ground fenced, until their upper rail shall be 3 feet 9 inches above the ground. The stake *e* is driven into the ground by the wooden mallet, fig. 706, at such a point as, where the stay *f* is stretched out from the flakes at the above inclination, that a peg shall fasten stake and stay together, as seen at *g*.

Fig. 703.



HURDLES OR FLAKES SET FOR CONFINING SHEEP ON TURNIPS.

After the first two flakes are thus set, the operation is easier for the next, as flake is raised after flake, and fastened to the last standing one in the manner described, until the entire line is completed.

1806. Each flake of this construction, with its fixtures, consists of fourteen pieces, viz., two side-posts *a*, four rails *b*, and three braces *c* and *d d*, which go to form the single flake; and one stay *f*, one stake *g* or *e*, and three pegs *h* or *i*, which are required for the fixing up of each flake. The scantling of the parts are the side-posts *a*, 4½ feet long, 4 inches broad by 2 inches thick. The rails *b*, 9 feet long, 3½ inches broad by 1 inch thick. The braces *d d*, two diagonals 5 feet 2 inches long, $2\frac{1}{4}$ inches broad by $\frac{3}{4}$ inch thick, and one upright *c*, 4 feet long, and of like breadth and thickness. The stay *f* is $4\frac{1}{2}$ feet long, 4 inches broad, and 2 inches thick, and bored at both ends for the pegs; the stake *g*, $1\frac{1}{2}$ foot long, pointed and bored. The pegs *h*, 1 foot long, $1\frac{1}{4}$ inch diameter.

1807. The preparation of the parts consists in mortising the side-posts, the mortises being usually left round in the ends, and they are bored at equal distances from the joining and stay pegs. The ends of the rails are roughly rounded on the edges, which completes the preparation of the parts; and when the flake is completed, its dimensions are 9 feet in length, and 3 feet 4 inches in breadth over the rails; the bottom rail being 9 inches from the foot of the post, and the upper rail 5 inches from the head.

1808. Another form of flake, which is by far more extensively employed, though by no means the best, consists of the same parts, except that it has always five rails, and the only material difference in the scantling is, that the rails are all $1\frac{3}{4}$ inch square. An essential difference also occurs in the preparation or manufacture of this kind of flake. The ends of the rails are all turned round by machinery, and the side-posts are bored for their reception, as well as for the pegs, by like machinery. The five rails in the flake are divided in height as follows: The bottom rail 9 inches from the foot of the posts; the spaces *between* the first and second, and the second and third rails, are each 7 inches, and the two upper spaces are respectively 8 and 9 inches, leaving, as before, 5 inches of the post above the upper rail.

1809. Flakes of this last description are extensively manufactured in Perthshire, where young larches are abundant, for of that wood they are generally made. Their price, when sold in retail by fifties or hundreds, is 1s. 9d. to 2s. each flake, including all the parts; sold in pieces, the expense of putting the parts together is usually 2d. each flake, including nails.

1810. The bar-flake, described in par. 1808, is not generally to be found in the market, and is chiefly made to order; the price about 2s. 6d. each flake, with fixtures.

1811. *Sheep Nets and Stakes.*—The other method of enclosing sheep on turnips or green forage is with *nets* made of twine of the requisite strength. These nets having square meshes when stretched upon the stakes, usually extend to 50 yards in length, and stand $3\frac{1}{2}$ feet in height. They are furnished with a rope along both sides passing through the outer meshes, which are called the "top" and "bottom rope," as the position of either may be at the time. These ropes are wound round the stakes by a peculiar sort of knot called the "shepherd's knot."

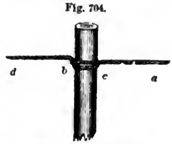
1812. The stakes are best formed of thinnings of ash-trees that have been planted very thick together, and grown up long and small, and they should be 3 inches in diameter and 4 feet 9 inches long; allowing 9 inches of a hold in the ground, 3 inches between the ground and the bottom of the net, and 3 inches from the top of the net to the top of the stake. Or they may be made of larch weedings, 4 inches in diameter and 4 feet 9 inches long; but every kind of wood of which they may be made should be seasoned with the bark on before being cut into stakes. They are pointed at one end with the axe, and that end should be chosen to be pointed which will make the stake stand in the same position as when it was growing in the tree; for its bark, it has been found, is then in the best state for repelling rain.

1813. Stakes are driven in this way: If the ground is in its usual soft state, the stakes may simply be driven into the ground with a hardwood *mallet*, fig. 706, in the line fixed on for setting the net, at distances of 3 paces asunder. Should the soil be thin and the subsoil moderately hard, a hole sufficiently large for a stake may be made in the subsoil with the foot-pick, fig. 382; but should the subsoil be so very hard as to require a larger hole to be made than what can easily be formed by the tramp-pick, or should the ground be so dry and hard as to require the use of any instrument at all, the most efficient one for the purpose is the *driver*, fig. 707. The stakes are thus driven so that their tops may not be less than 4 feet high, along as many sides of the enclosure as are required at the place to form a complete fence for the sheep.

1814. A net is set in this manner: Being in a bundle, having been rolled up on the arms and fastened together by the spare ends of the top and bottom ropes, these are unloosened and tied to the stake that has been driven close to the fence, whatever that may be, and then the net is run out in hand towards the right as far as it will extend in a loose manner, on the side of the stakes facing the ground the sheep are to occupy. On coming to the next stake from the commencement, the bottom rope gets a turn to the left round the stake, and the top rope above it a similar turn round the same stake, so as to keep the leading coil of the rope uppermost. The bottom rope is then fastened with the shepherd's knot to the stake, 3 inches from the ground, and the top rope is fastened with a similar knot near the top of the stake, stretching the net even and upwards; and in this way the net is fastened to one stake after another, until the whole of it is *set up*, as it is called, care being taken to make the top of the net run uniformly throughout its entire length.

1815. The shepherd's knot is made in this way: Let *a*, fig. 704, be the continuation of the rope which is fastened to the first stake, then press the second stake with the hand towards *a* or the fastened end, and at the same time tighten the turn round the stake with the other hand by taking a hold of the loose end of the rope *d*, and moving it so as to cause it to pass under *a* at *c*, and screwing it round the stake to *b*, where the elastic force of the stake will secure it tight under *a* at *b* when the stake is let go. The bottom rope is fastened first, to keep the net at the proper distance from the ground, and then the top rope is fastened to the same stake in the same manner. Proceed in this manner at each successive stake until the whole net is set up. A net may be thus set up either towards the right or the left as the starting-point may be situate, but in proceeding in either direction care must be taken to pass the top and bottom ropes round the stakes, so as the leading coil of the rope is always uppermost towards the direction in which the net is to be set up. Thus, in fig. 704, the rope *d* was uppermost until it was passed under *a*, because the setting of the net in this case is from right to left, and it continues to be uppermost until it reaches the next stake to the left. If both the cord and stake are dry, the knot may slip as soon as made, but if the part of the stake at *b* where the knot is fastened is wetted a little, it will make the rope keep its hold until the cord has acquired the set of the knot. With a new rope that is greasy, and the stake smooth, it is difficult for the knot to retain its hold even with the assistance of water.

Fig. 704.

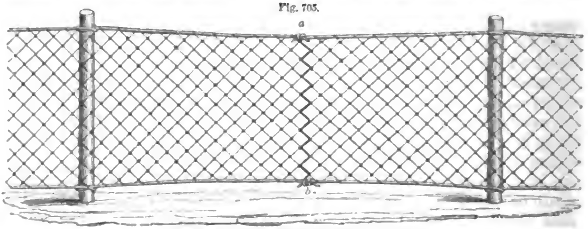


THE SHEPHERD'S KNOT

1816. There are some precautions required in setting a net, besides this of the ropes. If the net is new, the cords may be as tight as desired, because they will stretch considerably; but if old, the least damp or rain afterwards will stretch them so as to cause them to break. If the net is at all in a damp state, it should be set very tight, because rain cannot make it tighter; and if not set very tight, the first dry weather will so slacken the cords as to loosen all the knots, and make the net slip down the stakes; but even if it should not be slackened to that extent, it will be so slackened as to shake about with the wind, and bag down and touch the ground. Such an occurrence will create the trouble to the shepherd of resetting the whole net, and the best way of avoiding this trouble is to have the nets in a dry state when they are set. In wet weather, shepherds take the opportunity of a dry moment to set a dry net in anticipation along a new break of turnips, and they also hang up wet nets to dry on the outside of the stakes away from the sheep. Nets should never be wound up in a wet state, even for a short time, as they will soon mould and rot.

1817. On commencing the setting of another net, its top and bottom ropes are fastened to those of the last net, and the ends of the nets themselves are brought together by interlacing the meshes of both with a piece of string, as at *a* to *b*, fig. 705. Here the knots in the top and bottom ropes are seen, and the twine interlacing the meshes is made to appear stronger than that of the net only to

Fig. 705.



SHEEP-NET SET FOR CONFINING SHEEP ON TURNIPS.

let it be perceived. Thus one net is set after another, until the whole intended area is enclosed.

1818. Where there is a turn in the line of nets in going from one side of the enclosure to another, if there is much of the net left at the turn, it should be brought down the next side; in which case the stake at the corner should be driven very securely down, as there will be a considerable strain upon it from the nets pulling from different directions, and this will especially be the case in damp weather. But the safer and perhaps better plan is to take a fresh net at the turn, and fasten it to a stake, and run on the other net in its own line until it is expended in setting for future use, or to coil it around the top of a stake. All surplus ends of nets should be carefully hung upon the back of the stakes when wet, to dry and get the air. Part of the nets will thus cross ridges, and part will run along a ridge. Where they cross ridges that have been but once gathered up, or ploughed crown-and-furrow, the bottom of the nets will be nearly close to the open furrows; but where they cross a gaw-cut in rather strong land, a stake or two should be made to lie upon the bottom rope to keep it down, for some sheep have a trick of creeping under the net when they find a suitable opening; and where nets cross ridges which have been twice gathered up, one stake should be driven at one side of the open furrow, and another at the crown of the ridge, and the bottom rope will then run nearly parallel to the surface of the ground.

1819. In setting nets, in whatever position, care should be taken to keep each side of the enclosure in the same plane—that is, each side exactly in a straight line, and the surface of its nets perpendicular; and the different lines should meet at right angles to one another, so that every break of turnips occupied by the sheep should either be a rectangle or a square; because the strain upon the ends will then be equalised over the entire cords and stakes of each side, and no undue pressure be exerted on any one stake. A shepherd who knows his business so as to pay attention to these particulars, will preserve his nets and stakes a much longer time in a serviceable state, than one who is ignorant or careless about them.

Fig. 706.

THE SHEPHERD'S WOODEN MALLET.

1820. *The Wooden Mallet.*—The shepherd's wooden mallet, fig. 706, is best made of apple-tree, being least apt to split. The mallet is 12 inches long and 6 inches diameter, and the shaft is 3 feet long.

1821. *The Driver.*—The driver, fig. 707, is formed of a piece of pointed hard-wood, and strongly shod with iron, in a conical shape, and sharply pointed, and its upper end is protected from splitting by the strokes of the mallet, fig. 706, by a strong hoop of iron. The driver is altogether about 2 feet long.

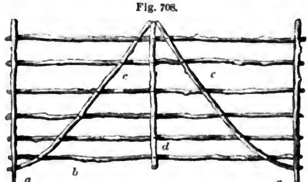
Fig. 707.

THE DRIVER.

1822. *The English Hurdle.*—The English hurdle is made of the crack-willow (*Salix fragilis*), and where that willow will grow, the farmer may have poles enough every year for making two or three dozen hurdles to keep up his stock. Hurdles can be bought ready-made at 16s. the dozen; when made at home they can be made for 4d. a-piece; and when the shepherd makes them they cost only his time. Hurdle-makers go round the country, and make at 4d. a-piece, and mend at 2d. each, finding their own tools.

1823. Willow-poles are thus treated in making hurdles: The butt-end of the pole is first sawed off; 4½ feet lengths make a pair of heads *a a*, fig. 708; 9 feet lengths make a pair of slots *b*; 5 feet lengths make a pair of stay-slots *c c*; and 3½ feet lengths make a pair of uprights *d*. The hurdle consists of two heads, six slots, two stay-slots, and one upright. The slots *b* are mortised into the heads *a*, and the mortises are made with centre-bit and tomahawk. The lower slots are placed nearer each other, as seen in the figure, and the strongest pair of slots are chosen for the highest and lowest of the hurdle. The top and bottom slots are nailed to the head, and then the upright is nailed on in the middle of the hurdle, and then the two stay-slots are nailed on to the slots. The nails are passed through gimlet-holes and clenched. The nails used are of the best iron, large-headed, and are what are called *fine*-drawn, not square, but rather flattened, to facilitate clenching, on which much of the strength of the hurdle depends.

Fig. 708.



THE ENGLISH WILLOW HURDLE

1824. The cost stands thus: 100 poles at 16s. make 36 hurdles, which, including workmanship and nails, cost £1, 11s. 6d., or 10s. 6d. per dozen. Although the horizontal slots are cut 9 feet long, the hurdle when finished is only somewhat more than 8 feet, the slot-ends going through the heads: 2 hurdles to 1 rod of 16 feet, or 8 to 1 chain of 22 yards, are the usual allowance.

1825. A larger kind of hurdle called the *park hurdle*, worth 2s. each, is made for subdividing meadows or pastures, and forms a sufficient fence for cattle. The small hurdle, fig. 708, is used for sheep, the larger to fence cattle, whereas the Scotch flake answers both purposes equally well, and is therefore more economical.

1826. An English hurdle is set in this way: The hurdles being carted to the field, they are laid down flat end to end, with their heads next to, but clear of, the line in which they are to be set, and, being light, they are easily handled for any purpose. A right-handed man works with the row of hurdles on his left. Having made a hole close to the fence for the foot of the first hurdle with the fold-pitcher, fig. 709, which is an iron dibber 4 feet long, having a well-pointed, flattened bit, in shape similar to the feet of the hurdles, he marks on the ground the place where the other foot is to be inserted, and then with his dibber he makes the second hole, which, like all the others, is made 9 inches deep. With the left hand the hurdle is put into its place, and held upright while lightly pressed down by the left foot on the lowest slot. This being done, the third hole is made opposite to and about 6 inches from the last. The dibber is then put out of hand by being struck in the ground near where the next hole is to be made. The second hurdle is then placed in position, one foot in the open hole, and the other foot marks the place for the next hole, and so on throughout the whole row. When the place of the second foot of a hurdle is marked on the ground, the hurdle itself is moved out of the way by the left hand, while the hole is made by both hands. When the whole row is set, it is usual to go back over it, giving each head a slight tap with the dibber to regulate their height, and give them a firmer hold of the ground.

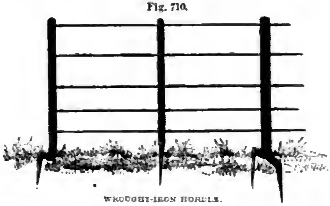
Fig. 709.

THE FOLD-PITCHER OR DIBBER FOR SETTING HURDLES.

1827. To secure the hurdles against the rubbing of sheep, couplings, or as they are commonly called, *copses*, are put over the heads of each pair of hurdles where they meet, which is a sufficient security. These couplings are made of the twigs of willow, holly, birch, or any other tough shoots of trees, wound in a wreath of about 5 inches diameter.

1828. *Young's Wrought-iron Hurdles.*—Fig. 710 represents wrought-iron hurdles of five round bars, as manufactured by Messrs C. D. Young and Co., Edinburgh. Each hurdle consists of three strong uprights, one at each end, and one intermediate between these. The lower extremities of the end supports are made with a strong double knee, terminating in a prong, this varying in length from a foot upwards. The middle upright is simply continued to a point, and twisted so as to present its flat side to the pressure. The horizontal bars—in the majority of instances round, but in some cases square, set diagonally—are "tannered" at the ends by machinery, which takes off the least possible proportion to form a shoulder for riveting them to the uprights.

Fig. 710.

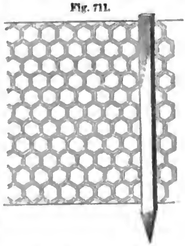


WROUGHT-IRON HURDLES.

1829. In erecting the hurdles, the two end uprights are placed against each other, the knees being in opposite directions; a series of double prongs is thus formed, which, being fixed in the ground, render the hurdles self-supporting, and obviate the necessity of using stays. In course of erection, the hurdles are fastened together by means of bolts and nuts, the bolts passing through bolt-holes made in the end uprights.

1830. For horses, cattle, sheep, and lambs, the price of this form of hurdle is from 2s. to 4s. per lineal yard; for sheep and lambs only, 2s. 6d. to 3s.

Fig. 711.

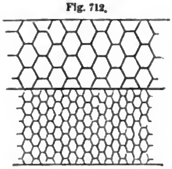


WIRE-NETTING AND STAKE

1831. *Barnard and Bishop's Sheepfold Hurdles.*—Messrs Barnard and Bishop manufacture a sheepfold iron hurdle invented by Henry Gilbert of Kensington, Middlesex. They are 12 feet long, are perfectly flat, and are easily removed from place to place by means of a light iron wheel, which is readily attached to each hurdle. Price, 16s.; the cost of a wheel, 10s.

1832. *Wire-Netting.*—As a substitute for the twine nets used for enclosing sheep on turnips, wire-netting is now much used. In fig. 711 we give an illustration of Messrs Young's strong premium wire-netting for sheep; its height is 3 feet, and the price per lineal yard is 1s. 3d.

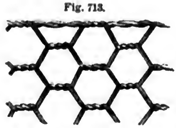
Fig. 712.



MIXED GAUZE WIRE-NETTING

1833. Fig. 712 illustrates the "mixed mesh-wire game-netting," manufactured by Messrs Barnard and Bishop, Norfolk Wireworks, Norwich. By making the upper part of the netting of a larger-sized mesh than the lower, the price is proportionably reduced; to work together, the upper mesh must be twice the size of the lower. This can be made to any height under 8 feet. With meshes 1 and 2 inches, wire No. 19, the price per lineal yard, 2 feet wide or high, is 9d. when japanned, 10½d. when galvanised; with meshes 1½ inch and 3 inches, No. 19 gauge, 5d. and 6d.; with meshes 2 inches and 4 inches, No. 19, 4¼d. and 5¼d.

Fig. 713.

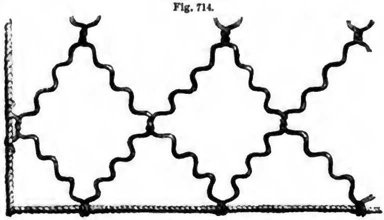


WIRE-NETTING.

1834. In fig. 713 is given the ⅝-inch mesh wire-netting, manufactured also by Messrs Barnard and Bishop, suitable for various purposes; the price per square foot, wire No. 20, being 5½d. japanned, and 6d. galvanised.

1835. In fig. 714 is illustrated a recently-introduced form of spiral wirework, invented by Mr J. Reynolds, of 27 New Compton Street, Soho, London. It is made of hard twisted wire, galvanised after being manufactured. From the way in which the twisted wires are interlaced, no other fixing is required.

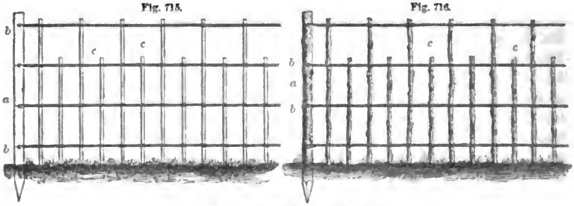
Fig. 714.



SPIRAL WIRE-WORK.

1836. *Macpherson's Portable Sheep-Hurdle.*—A new kind of sheep-fence has lately been invented by Mr Alexander Macpherson, Old Mill Cottage, Carstairs, Lanarkshire. It consists of a series of four parallel ropes, embracing within their strands thin fillets of wood placed at such distances as are desirable for a fence. Figs. 715 and 716 show the appearance of this fence, where *a*, *a* are stakes, to which the ropes *b b*, are fastened by means of

Fig. 715. Fig. 716.



MACPHERSON'S PORTABLE SHEEP-HURDLE.

hooks to staples driven into the stakes: *c c* are fillets of wood embraced in the strands of the ropes. The fence is made by machinery, the ropes being spun from tarred twine, and the fillets are inserted between the strands of the twine while the rope is being spun at such distances and of such lengths as is desired to make a fence of determined dimensions. In fig. 715 the fillets *c* are of larch prepared in a saw-mill, and those *c* of fig. 716 are of spruce branches, which are well known to be the most durable of small round timber.

1837. In setting this fence the material is divided into lengths of 10 yards, where stakes *a* are driven provided with staples. The ends of the ropes *b* of that length have hooks, which lay hold of the staples on the stakes, and the ropes are supported by a stake at every 2½ yards. The fillets of timber are 3½ feet long and ⅝ or ¾ inch square. If desired, the intermediate fillets may be made shorter, as seen in the figures. The staples of each stake take in the ends of two lengths of rope of 10 yards long. Two men will erect from 800 or 1000 yards a-day, and 1000 yards weigh 40 cwt. with their stakes. The tarred hemp for every 100 yards of fencing costs from 12s. to 24s., according to weight and strength. The cost of the fence is from 6d. to 10d. per yard according to the same conditions.

1838. Mr Macpherson's fence-machine can spin wire instead of the hemp-cord, and make a fence with annealed or galvanised wire that will last for many years.

Fig. 717.

THE SHEPHERD'S CROOK.

1839. It seems to us that this sort of fence with wire, or even with the tarred hemp-cord, would make an excellent fence in high pastoral districts along march-fences, where both wood and stone may not be at hand, its closeness securing sheep better than a common wire-fence; and if it were erected on a turf wall, even black-faced sheep might be confined within the bounds of their hirsels, without much trouble to the shepherds and their dogs, and much quietness to themselves.

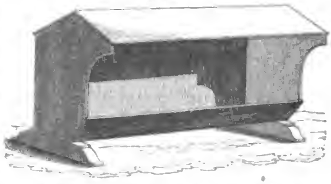
1840. *The Shepherd's Crook.*—The crook is a useful implement to the shepherd for securing any individual sheep he may desire to seize without disturbing the flock. It consists of a round rod of iron bent in the form as shown in fig. 717, and terminating at one end in a knob, and at the other in a socket which receives a helve of 5 or 6 feet in length. The crook, as placed in the figure, is held by the shepherd so as to seize the near or left hind-leg of the sheep, which enters by the narrow passage *a* into the wider space towards the top of the crook, out of which the leg easily escapes when the sheep has been seized by the shepherd.

1841. *Turnip-Trough for Sheep.*—Fig. 718 is a simple and convenient form of trough for containing the turnips as they fall sliced from any of the turnip-slicers. Its most convenient length is 8 feet, and it should be acute at the bottom, for the more easy seizure of the pieces of turnip by the mouths of the sheep, and it is so made by nailing two boards, of 9 inches in breadth, upon the two triangular-shaped ends, and in the niches formed in the two billets of wood to serve for feet. The troughs are set in a line along the outside of the two rows of turnips about to be pulled for slicing. The wheelbarrow turnip-slicer, fig. 535, is wheeled to each trough successively by one field-worker, who works the handle, and the hopper is filled by another worker who tops and tails the turnips. The sheep range themselves on both sides of the trough.

Fig. 718.

THE TURNIP-TROUGH FOR SHEEP-FEEDING.

Fig. 719.

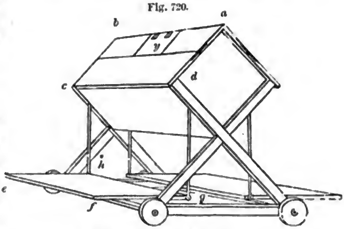


THE OILCAKE OR CORN-TROUGH FOR FEEDING SHEEP.

1842. *Corn-Trough for Feeding Sheep.* — Sheep, while on turnips, are fed with other substances, such as oilcake or corn. Either of these is best served in a covered trough, such as fig. 719, to protect it from the weather. Its construction is very much like fig. 718, with the addition of the ends and backs being raised, and the top covered in.

1843. *The Platform Corn-Box for Sheep.* — An ingenious mode of preserving corn dry for sheep on turnips has been tried with success in Fife. It consists of a box like a hay-rack, fig. 720, in which the corn is at all times kept closely shut up, except when the sheep wish to eat it, when they get at it by a simple contrivance. Into the box *a b* the corn is poured through the small hinged lid *y*. The cover *c d*, concealing the corn, is also hinged, and when elevated the sheep have access to the corn. Its elevation is effected by the pressure of the sheep's fore-feet upon the platform *e f*, which, moving as a lever, acts upon the lower ends of the upright rods *g* and *h*, raises them up, and elevates the fore part of the cover *c d*, under which the heads of the sheep then find admittance into the box. A similar apparatus gives them access to the other side of the box. The whole machine can be moved about to convenient places by means of the four wheels.

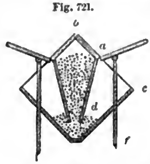
Fig. 720.



THE CORN-BOX FOR SHEEP ON TURNIPS

1844. The construction of the interior of the box being somewhat peculiar, another, fig. 721, is given of a vertical section of it, where *b* is the hinged lid by which the corn is put into the box, whence it is at once received into the hopper *d*, the bottom of which, being open, and brought near that of the box, a small space only is left for the corn to pass into

Fig. 721.

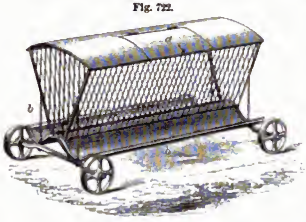


THE VERTICAL SECTION OF THE INTERIOR OF THE CORN-BOX.

the box, the hopper *d* forming the corn-store ; *a* is the cover of the box raised on its hinges by the rod *f*, acted upon by the platform *e f*, fig. 720, and when in this position, the sheep put their heads below *a* at *c*, fig. 721, and eat the corn at *d*.

1845. *Kirkwood's Wire Sheep-Fodder Rack.*—In fig. 722 we give a view of a wire sheep-fodder rack manufactured by Mr James Kirkwood of Tranent. It consists of wirework, the body being 6 feet long, 2 feet 9 inches wide at top, 8 inches wide at bottom, and 2 feet 3½ inches in depth. The cover consists of sheet-iron, curved to throw off the rain, and the fodder is put into the rack by throwing open the hatch *a* in the cover. The refuse from the fodder, such as hay, falls upon the troughs *b b*, made also of sheet-iron, and may be eaten by the sheep, and at all events saved from being trodden into the ground. The troughs are provided with a hole at each end to allow the rain to drain off, and might be used in dry weather for holding salt, oilcake, or corn for the day. The machine is mounted on axles and wheels, and may be moved to any desired spot. The price of it is £4, 11s.

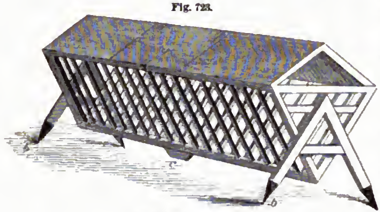
Fig. 722.



KIRKWOOD'S WIRE SHEEP-FODDER RACK.

1846. *Sheep Straw or Hay Rack.*—Fig. 723 gives a very convenient form of straw-rack for sheep on turnips, containing plenty of straw at a time, admitting the straw easily into it, being easily carried about, of easy access to the sheep, and being so near the ground as to afford excellent shelter to them. Three or four of these racks may be so placed as to afford ample shelter to a large number of sheep in a stormy period.

Fig. 723.

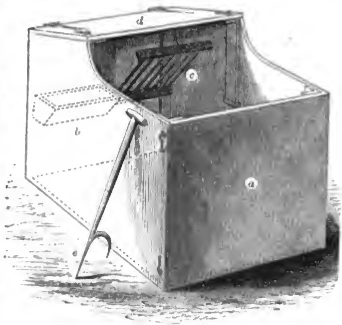


THE SHEEP STRAW OR HAY RACK.

1847. It is made of wood, 9 feet in length, 4½ feet in height, and 3 feet in width, having a double-sparred rack, and covered with an angle roof to throw off the rain. The rack is supported on two triangular-shaped tressles *b b*, shod with iron at the points, which are pushed into the ground and take a firm hold of it, and act as stays against the wind. The billet *c*, attached to the middle of the bottom bar of the rack, rests upon the ground, and supports the rack from being bent down in the middle. The lid *a* is opened on hinges when straw is put into the rack. Such racks, even when full of fodder, are easily moved about by two persons, and, as a means of shelter, their position should be changed with a change of wind.

1848. *The Ewe-House.*—In case of an individual ewe of a large flock of a pastoral farm straying from its shelter-shed, or suffering in hard labour, or having a weakly lamb or twins which are apt to stray from her, or being overtaken by a rude blast after lambing, a temporary shelter to such a ewe may be the means of saving the lives of herself and lambs. Mr Nicholas Burnett, Blaik Hedley, near Gateshead, has used such a shelter with success; and as such a structure as is seen in fig. 724 is not costly, a number may be used at a time.

Fig. 724.



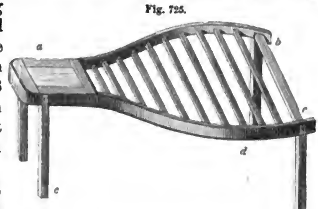
EWE-HOUSE.

1849. It consists of an enclosure of boards, or a box, fig. 724, where *a* is the front, removable by hooks to admit the ewe and her lamb; *b* is a manger to contain cut turnips, or corn, or oilcake; *c* a rack for hay. To fill both rack and manger, access is found by the lid *d* on its hinges.

1850. Its dimensions are $5\frac{1}{2}$ feet long, breadth 3 feet, height 3 feet; breadth of the covered part *d* 2 feet 7 inches, and rise of the slope at *d* 7 inches. The hook *e* serves to secure the ewe to the ground by the neck while lambing, but is not a necessary appendage to the ewe-house.

1851. *The Bathing-Stool.*—A useful implement in bathing sheep is the bathing-stool, fig. 725, which is made of the best ash. It consists of a seat *a*, for the shepherd to sit on while bathing the sheep, 1 foot square; the sparred part is 3 feet long, and 30 inches wide in front from *b* to *c*, its greatest width being across at *d*. The legs *e e* are 18 inches high, and fixed by means of iron rods passed through their upper part and the frame of the stool, and secured with nut and screw.

Fig. 725.



BATHING-STOOL FOR SHEEP.

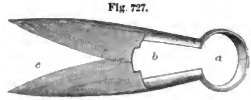
1852. *The Bath-Jug.*—A tin flask, easily holding a quart, and provided with a handle and a long crane-like spout, small at the end, is used to pour the bath along the shedded rows of the fleece, and is represented by fig. 726.

Fig. 726.


BATH-JUG.

1853. *The Wool-Shears.*—The instrument by which wool is clipped off sheep is named *wool-shears*, as seen in fig. 727. They require no particular description farther than to explain that the *bowl a*, which connects the two blades, acts as a spring to keep them separate, while the pressure of the hand on each side of the handle *b* overcomes the spring and brings the cutting edges of the blades together. There are wool-shears which have additional springs placed between the handles *b* to separate the blades more forcibly, but are not so agreeable to the hand as the simple bent spring *a*. Sometimes the spring of *a* is as strong

Fig. 727.

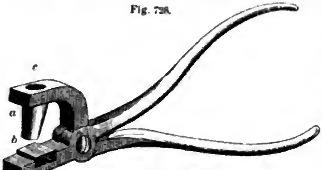


WOOL-SHEARS.

as soon to tire the hand, to relieve which a piece of cord is wound slackly round the handles. Strong shears are more easily worked if held near the blades; but if the backs of the blades are pressed upon, they will soon hurt the hand. When not in use, the blades are held together by their points being passed through a ring of leather. A rag-stone is used to sharpen wool-shears. The cost of the shears is from 2s. 6d. to 3s. 6d. a pair. A shepherd requires two or three pairs to do other jobs, as to remove clotted locks of wool, and he makes it a rule to use the clipping-shears on no other occasion than at the regular shearing.

1854. *The Punching-Nippers.*—Fig. 728 are the ***punching-nippers***, used for marking lambs, of which the inverted hollow cone *a*, having its small end sharpened, is employed to cut the hole out of the ears; and to save the ears from being unduly pinched, a pad of horn *b* is inserted into the straight under-arm of the nippers, and the pieces nipped out rise out of the orifice *c*, which is enlarged at the upper end. The figure at once shows how the instrument is used, being similar to the one used by shoemakers to punch holes into the lappets of shoes, through which the shoe-ties are passed. It costs 2s. 9d.

Fig. 728.



PUNCHING-NIPPERS.

1855. *The Buisting-Iron.*—Buisting consists of stamping a letter or letters, expressive of the initials of the name of the owner or of that of the farm, or of both, upon the body of a sheep. The buist or mark is effected by a simple instrument *a*, fig. 729, which carries the capital letter S. The material of which the buist is made is boiled tar, made viscid by a little pitch, and is put on when hot.

Fig. 729.

Fig. 730.

BUISTING AND BRANDING IRONS.

1856. *The Branding Iron.*—Fig. 730 represents an iron having the letter S on it, which is used for branding the initials of the owner or of the farm upon the horns of cattle and sheep. It is made red hot in the fire when the brand is effected on the horn. On the continent of Europe such a brand is not unfrequently seen upon the skins of horses and cattle.

1857. *The Trochar for Hydatids.*— Sheep are at times affected by a complaint named the ***sturdy.*** It is caused by the lodgment of an hydatid on the brain. The hydatid is removed and the cure of the sheep effected by the instruments represented in fig. 731. The disease causes the sheep to appear stupid, turn round and separate itself from its neighbours. On examining the head between the ears a softening of the skull will probably be discovered on a limited spot, which is the seat of the disease. The trochar *a*, with its canula *b*, is inserted through the soft part of the skull, and it will pierce the hydatid. On withdrawing the trochar and leaving the canula, the pipe of the syringe *c* is introduced through the canula to the hydatid, and its watery substance is sucked up by the syringe. The canula is then withdrawn, and the sac of the hydatid is extracted by the pliers *d*.

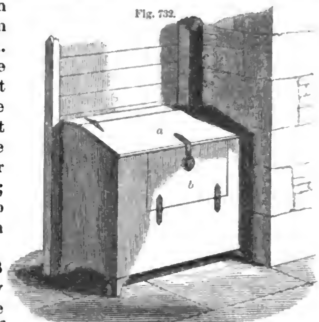
Fig. 731.

TROCHAR FOR HYDATIDS.

When the bone of the skull is not very soft, the piercer *e* is used to make the hole in it for the trochar, the guard of the piercer being placed at such a distance up its screwed shank as to allow the piercer to reach no farther than the hydatid.

1858. *The Corn-Chest.*—The most convenient form of corn-chest for horses is when it is high and narrow, as is shown in fig. 732, which takes up less room on the floor than when low and broad. It is 5 feet long, $4\frac{1}{2}$ feet in height at the back above the feet. A part of the front *b* folds down to gain easier access to the corn as it gets low in the chest. Part of the lid *a* is made fast to receive the end of the spout *c*, which has its upper end in the floor of the granary above; and to make the movable part lighter to open and shut, the lid is fastened with a hasp and padlock.

Fig. 732.



CORN-CHEST.

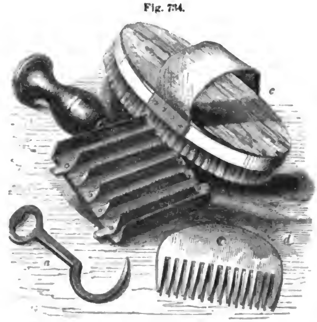
1859. *The Whin-Bruiser.*—Fig. 733 represents a sort of rammer that may be used for bruising whins or furze when horses are fed on that species of food. It consists of a shank of wood *a*, 3 feet 8 inches in length, a bulged-out part *b*, to give the instrument weight on being used, and a base *c*, which is contracted into a square, and shod with an iron shoe embracing parallel iron-cutters, 1 inch asunder and 3 inches deep, and sharpened at their lower edge.

1860. Old whin-plants growing in a fir plantation afford the longest and most succulent and tender shoots for being bruised into fodder for horses.

Fig. 733.

WHIN-BRUISER.

Fig. 734.

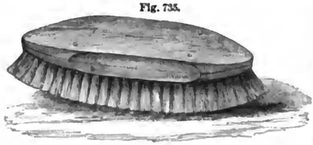


CURRY-COMB, BRUSH, FOOT-PICKER, AND MANE-COMBS

1861. *The Curry-Comb, &c.*—Fig. 734 gives a collection of necessary implements for the stable, whether of the farm horse or the riding stable: *a* is the foot-picker for picking the feet clean, *b* the curry-comb for removing the grosser dirt from the hair, *c* the brush for sweeping the loose dirt out of the hair, and *d* the mane-comb for dressing the long hair of the mane and tail. Every ploughman and groom should be provided with these necessary implements.

1862. *The Water-Brush.*—The water-brush, fig. 735, is useful in washing down the mud off a horse's legs and belly with warm or cold water in winter, instead of wading the horse through a pond, and it removes the mud from the skin much more quickly and effectually than any amount of wading in water.

Fig. 735.



WATER-BRUSH.

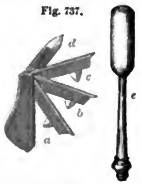
1863. *Docking-Iron.*—Young horses are docked before being put to work on the farm. Docking consists in amputating the last six joints of the tail, and is effected by the instrument represented in fig. 736. A docking-iron consists, first, of a semicircular plate of iron with a sharp edge on the curved side, to one side of which is fixed a handle of wood in a split socket, and at the other side is forged an eye for a joint; and, secondly, of a piece of hardwood, out of one end of which is cut a semicircular notch of less diameter than the cutting plate of iron, and the other end is lengthened out into a handle. A double-eyed stud of iron is fixed at the farther end of the notch, and into this is jointed the eye of the cutting-plate. The tail of the horse, as far as it is desired to be amputated, is made to rest in the semicircular notch, and the cutting-plate being brought upon it, is pressed with a firm and decisive force on bringing together both the handles. The horse's tail is prepared for the operation by clipping away the hair from the part on which the cutting instrument is to act.

Fig. 736.

DOCKING-IRON.

1864. *Fleam and Blooding-Stick.*—In case of sudden inflammation in either cattle or horses, a fleam and blooding-stick, to let out blood, are necessary instruments to be always in the possession of the farmer. Fig. 737 represents these instruments: *a* is a fleam for young animals,—*b*, that for the horse being small; *c* that for cattle being large; *d* is a lancet; *e* is the blooding-stick, of hardwood turned, having a cylindrical end enlarged for weight to give impetus to the blow upon the fleam. Fleams are sharp-pointed triangular blades of steel inserted each into the edge of a thick short bar of iron.

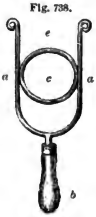
Fig. 737.



FLEAM AND BLOODING-STICK.

1865. *The Balling-Iron.*—It is necessary at times to give a medicinal ball to a horse, and as few grooms are expert at administering a ball without assistance, a balling-iron affords them that assistance. Fig. 738 represents the form of a good balling-iron: *a a*, a branched round rod of iron, is fixed to a hooped handle *b* by means of a tine, and a circular ring *c* of the same description of iron is fixed between the branches. The instrument is used by inserting it by the handle in a horizontal position into the horse's mouth, and on turning the handle down, the circular ring acting on the inside of the mouth, opens it, the lower jaw passing into the opening *d*, while the upper rests on the ring at *e*.

Fig. 738.

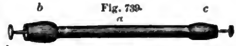


BALLING-IRON.

The hand, with the ball, can then with safety be introduced into the mouth through the ring *c*.

1866. *The Ball-Syringe.*—Even with the assistance of the balling-iron, fig. 738, a ball may not be easily administered to a refractory horse; a ball-syringe, fig. 739, may then be used with advantage. It consists of a hollow tube *a* of wood, terminating with a cylindrical cup, *b* or *c*, of a different size at each end. An iron rod traverses the hollow of the tube, of a length longer than the tube, and furnished at each end with a circular hollow disc *d* or *e*, of a diameter equal to that of the cylindrical cup which receives it. The ball to be given to the horse is put either into *b* or *c*, a small one into *c* and a large one into *b*, the rod being drawn back to permit the full entrance of the ball into the cup. The tube is then introduced into the horse's mouth through the ring *c*, fig. 738, as far as practicable, and the ball is projected into the gullet beyond the tongue by a push of the rod *d e*.

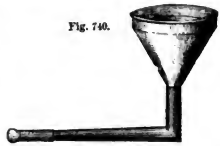
Fig. 739.



BALL-SYRINGE.

1867. *The Clyster-Funnel.*—The old syringe, and bladder, and pipe, will now be laid aside to use the funnel as constructed in fig. 740, when a clyster is to be administered to a horse or cow. The funnel consists of an ordinary-shaped cone of tin, furnished with a tin pipe bent at right angles, and terminating in a nozzle of wood. On inserting the nozzle, the fluid is poured into the funnel, and simply by gravity finds its way by gentle degrees into the bowels of the animal.

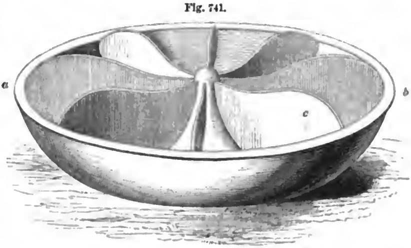
Fig. 740.



CLYSTER-FUNNEL.

1868. *The Round Pigs'-Trough.*—In fig. 741 we illustrate a form of pigs' trough for standing in the middle of a court. It is made of cast-iron in one piece. The diameter of this trough is 30 inches, the edge *a b* is finished with a round baton, serving both for strength and comfort to the animals who eat out of it; the depth is about 9 inches, and it is divided into eight compartments by the divisions *c*, which are formed with a convexity on the upper edge, to prevent the food being thrown from one compartment into the other. This trough stands upon the top of the litter, is not easily overturned, the cattle cannot hurt themselves upon it, while it is easily pushed about to the most convenient spot for it to stand.

Fig. 741.

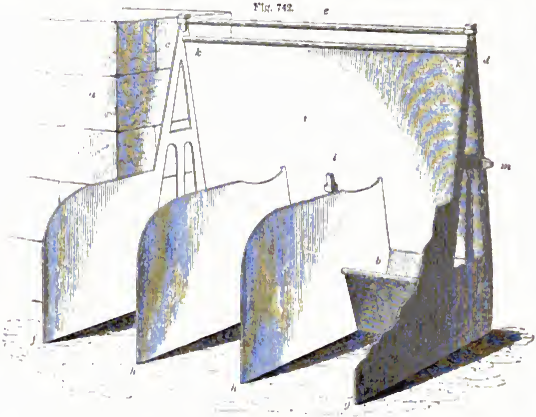


ROUND PIGS'-TROUGH, TO STAND IN A COURT.

1869. *The Subdivided Pig-Troughs.*—A very convenient trough for a number of feeding pigs has been long manufactured by the Shotts Iron Company, of which fig. 742 is a view in perspective from the interior of the court. It is nearly all made of cast-iron, and possesses the great convenience of allowing the troughs to be filled with food from the outside of the building, the feeder being at the same time free of any annoyance from the inmates. Troughs of this kind are placed in proper-sized openings in the external wall of the piggery court, in the manner shown in the figure, where *a* marks the wall on one side of the opening—

that on the hither side being left out of the figure, in order to exhibit the form of the trough. The trough, part of which is seen at *b*, is 4 feet in length, 16 inches wide at top, and 8 inches at bottom, and is 9 inches deep. The two ends

Fig. 742.

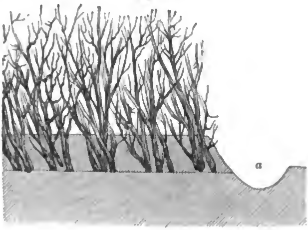


FIGS. TROUGHS WITH SUBDIVISIONS, TO STAND IN AN OPENING OF THE OUTER WALL OF THE PIT.

c and *d* rise in a triangular form to the height of 3½ feet, and are connected at the top by the stretcher-bolt *e*. The lower part of each end extends inward to *f g*, making a breadth of 3 feet 4 inches when complete; but this part of the end *g* in the figure is broken off, to show part of the trough *b*. Two intermediate divisions *h h* divide the trough into three compartments—these divisions extend to the same length as the ends *f g*, and are all 21 inches in height. By means of these divisions, each animal, when there are more than one together, has its own stall, and can take its food undisturbed by its neighbours. A swing-door *i* is jointed in the pivots *k k* to complete the form by filling up the opening of the wall. In the figure this is thrown outward to the full extent, where it always stands during the time the animals are feeding, and is fixed there by a slide-bolt in the inside. When food is to be introduced, the bolt is withdrawn, and the door moved from that position to *l*, and then bolted till the compartments of the trough are cleaned and filled, when the door is again swung back to its original position, and the food is placed before the animals. The door has slits in it corresponding to the divisions *h h*, to allow of its swinging freely, and yet to have depth sufficient to close the entire opening down to the outward edge of the trough. A dowel or stud *m* is let into the wall to secure the upper part of the trough.

1870. *The Dead-Hedge.*—A dead-hedge is formed of the smaller branches of a hedge that has been cut down. It is represented by fig. 743. Bundles of the cut thorns are made about 4 feet long. A trench is made in the ground as at *a*, by the spade, in the line in which it is desired to erect the dead-hedge. The thick end of the bundle is inserted into the trench, and earth from the succeeding trench is thrown upon the end of the bundle. The trench will be about 9 inches in depth, so that the dead-fence will stand about 3 feet 3 inches in height. The figure does not give the dead-hedge in so massive a form as it really has, but the ground on which it stands being given in section, the position of one bundle with the others is distinctly enough shown.

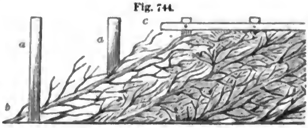
Fig. 743.



DEAD-HEDGE.

1871. *The Stake-and-Rice Fence.*—A stake-and-rice fence is formed of ordinary stakes and the branches of forest trees. It is seen in fig. 744, where *a a* are stakes, 4½ feet long and 4 inches square, and, after being pointed with the axe, are driven into the ground in the line of fence desired to be erected, from 4 to 6 feet asunder, according to the length of the branches. The branches are then set with their butt-ends upon the ground as at *b*, and inclined in the fence at an angle of 45°, and wound alternately before and behind the stakes as far as they will reach. A neat and stout finish is given to the fence by nailing a single rail of paling along the top of the stakes, as at *c*.

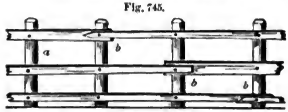
Fig. 744.



STAKE-AND-RICE FENCE.

1872. *The Common Wooden Paling.*—The paling is a very common mode of fencing where wood is at all plentiful; and where such is the case, it forms a cheap fence at first, and will last several years. Fig. 745 represents a three-railed paling. Fir trees of 8 inches in diameter afford good materials for palings on being quartered for stakes of 4½ feet in length, and cut up in deals of 3½ inches broad for palings. The stakes *a* are driven 12 inches into the ground with a mallet, fig. 706, at 5 or 6 feet asunder; and when the ground is hard, a hole should be made for them by the foot-pick, fig. 382, or with the driver, fig. 707, and such stakes will support a paling of 3 feet 3 inches in height. Two rails are sufficient to fence cattle, but three are required to make a close enough fence for sheep. The rails are nailed on the face of the stakes next the field to be fenced, and they should be made to break joint, so as the ends of all the three rails should not be nailed on the same stake; nor should the broad ends of the rails be nailed together, but the broadest and narrowest as at *b b b*, that the strength and weight of the rails may be equalised. To make the paling more secure where desired, a stake should be driven as a stay in a sloping direction behind the rails, and nailed to every third stake. The upper edge of the upper rail should be fastened near the top of the stake, the lowest edge of the lowest one 6 inches, and the upper edge of the middle one 20 inches from the ground. The best nails for palings are called "Scotch-made stout paling-nails," from 3 to 3½ inches in length. Such a paling, when wood is plentiful, costs 1s. 2d. per rood of 6 yards, and where it is scarce, 2s. per rood. Charring the points of the stakes increases the cost, but renders them much more durable. Painting them as far as they are driven into the ground with coal-tar allowed to become dry, is perhaps as good a means of preservation.

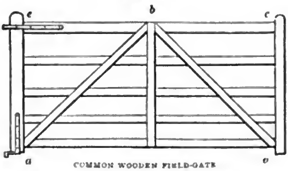
Fig. 745.



COMMON WOODEN PALING.

1873. *The Common Wooden Field-Gate.*—The wooden field-gate, represented by fig. 746, is the most common form of field-gate in this country. It consists of a strong stile *a e*, upon which the gate acts; a light stile *c d*; five horizontal bars, such as *e c* and *a d*; an upright bar in the middle *b*; and two diagonals *a b* and *d b*. The principal stile *a e* is furnished at the top-rail with a band of iron, the tails of which embrace both sides of the stile and rail, and is fastened to them by bolts and nuts. The eye of the band is hung upon the crook fastened to the hanging-post *d* of the gate, fig. 73 (which see). The lower end of the stile *a e* is supported upon a heel-post of iron, consisting of tails which embrace the stile, and are fastened to it with bolts and nuts, and of a triangular palm of iron kneed at right angles to the tails, as seen at *a* in the figure, and at the apex of which palm is forged at right angles a pin which rotates, as the gate is opened or shut, in a shallow hole on a strong hard stone placed there on purpose to support the entire weight of the gate. In order to allow the gate to remain steady in any position, the centre of the eye of the band *e*, and the axis of the pin of the heel-post *a*, must range in a perpendicular line. We have shown, in par. 254, that this form of wooden gate is constructed contrary to principle.

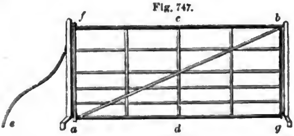
Fig. 746.



COMMON WOODEN FIELD-GATE.

1874. *The Iron Field-Gate.*—Gates of iron in the fields are not so common as of wood, but they are increasing, and it is not improbable they may yet supersede the wooden. Fig. 747 represents a good form of iron gate for fields. The gate consists of six parallel bars of iron, such as *f b* and *a g*. These are fastened together at both ends by means of the stiles of iron *a f* and *b g*. The bars are prevented from twisting by the three transverse bars of iron, such as *c d*. The fore stile *b g* cannot drop because of the diagonal bar of iron *a b*. The gate is supported by the strong post of iron at *a f*, and which is strengthened in its position by the stay *e*, rising from the ground to two-thirds of the height of the post. The gate closes upon the iron post at *b g*. For a demonstration of the correctness of the principles upon which this iron gate is constructed, see par. 329.

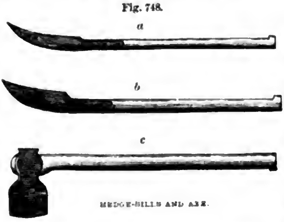
Fig. 747.



IRON FIELD-GATE.

1875. *Hedge-Bills and Axe.*—Hedge-bills have flat, broad, curved, pointed, blades of iron, hardened into cutting edges, and terminating at one extremity by a split socket, into which a flattened helve of ash is fixed. *a*, fig. 748, is the switching-bill for switching off the superfluous shoots of hedges; its curved blade is 9 inches long and 1½ inch broad; its helve 2 feet 3 inches in length: this bill weighs 2½ lb. *b* is the breasting-bill for breasting over hedges; it is shorter in the blade, but is stronger and heavier than the switcher, and costs from 3s. the English

Fig. 748.

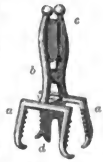


HEDGE-BILLS AND AXE.

to 7s. 6d. the Scotch price. The Scotch-made implement is much the better of the two. The hedger's axe *c*, weighs 3 lb., and its helve is 3 feet in length, and costs from 1s. 8d. to 2s. 6d. without the helve, ranging from No. 1 to No. 4. It is used for cutting down old hedges to the ground.

1876. *The Mole-Trap.*—The long used cylindrical wooden mole-trap is becoming obsolete, and new forms and material have been introduced to supersede it. Among the best of these introductions is that in fig. 749, which is made entirely of iron. It consist of two jaws *a a*, as shown in the figure, connected together at *b* by a joint. Above the joint *b*, and between the arms, is placed a double plate of steel *c*, which acts as a spring. The instrument is set upright, as in the figure, in the run of the mole, and the mole, meeting with the obstruction, pushes forward, and displaces the small notched plate *d*, which is set between the jaws to keep them separate, and the spring *c* close; and on the removal of the plate *d* by the mole, the spring *c*, on being released, forces the jaws *a a* to close upon the mole and to kill it.

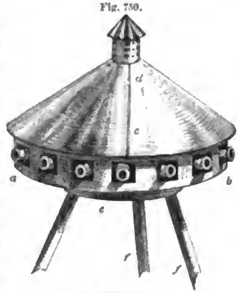
Fig. 749.



MOLE-TRAP.

1877. *Rook-Battery.*—In fig. 750 we illustrate a form of rook-battery. Gunpowder is the most effectual means of any of scaring birds from fields. Rags steeped in a solution of gunpowder, dried, and placed on the windward side of a field, will act as a scare as long as they last, but the renewal of them is troublesome. We contrived an apparatus, which we named a *rook-battery*, to keep up a fire throughout the day, with little trouble. It is seen in perspective in fig. 750. It consists of a circular plate of strong tin, *a b*, eighteen inches in diameter, upon the circumference of which is soldered a hoop of equally strong tin, 3 inches in height, and through which are pierced twenty-four embrasures, three quarters of an inch square each, at equal distances from one another. At each embrasure is mounted a brass cannon, 4 inches in length, upon a carriage soldered to the bottom-plate, and removable at pleasure by means of a clasp. The plate and rim are covered by a conical tin top, *c*, similar to the cover of a street lamp, with an eave projecting one inch to prevent the drip of rain running down the rim. The cover is surmounted with a cylindrical lantern *d*, $2\frac{1}{2}$ inches high, pierced with holes. The cannon are loaded with fine gunpowder, and wadded with woollen wadding to prevent its ignition. They are fired with a match consisting of cotton thread dipped in a solution of saltpetre; and the thread is brought over and held upon the touch-hole of each cannon, by a bit of copper-wire attached to the carriage. The match-thread is made longer and shorter as the time is determined on between the discharge of each cannon; and to dispose of it for this purpose, the central part of the plate *a b* is divided by perpendicular partitions of tin, so arranged as to form numerous alleys, along which the match-thread is made to traverse at such length as to burn down in time to reach the touch-hole at the given hour. Plate *a b* is affixed to a circular board *e*, 9 inches in diameter, and 1 inch in thickness, and in its circumference are attached three legs, *f f f*, which support the apparatus in tripod form, at such a height as to elevate the apparatus above the standing corn.

Fig. 750.



ROOK-BATTERY.

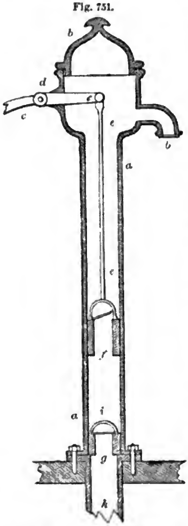
1878. The battery is placed in the part of the field most frequented by the rooks, and where it may best be seen. Suppose that the guns are loaded and the match lighted at five in the morning, and that by eight at night it is time to cease firing, which is fifteen hours, in which time thirty-seven and a half minutes will require to elapse between the discharge of each of the twenty-four cannons. Such discharges are much more to be depended on for regularity than the firing of any fowling-piece by a herd-boy. Batteries could be made of any size, and to fire as often as desired; and the smaller-sized ones, when longer in use than the firing of all the cannons can reach the time, these might be loaded oftener than once a-day.

1879. In addition to the discharges of the guns, if a piece of woollen rag, steeped in a solution of gunpowder and dried, were placed in a cup of tin at *d*, immediately below the lantern of the cover, and set fire to, the smoke arising from it would still further intimidate the rooks, and enable the discharge of the cannons at longer intervals to suffice. Both these means would also serve to intimidate pigeons and small birds.

1880. The position of the battery should be changed every day, and a piece of laid corn is the best spot for erecting it on to be most seen from a distance. It may be set amongst potatoes, as also in a plot of turnips growing for seed.

1881. The number of such apparatuses required for a farm would depend on the number of the cornfields subject to the attacks of birds, and also on the succession in ripening of the different crops.

Fig. 751.

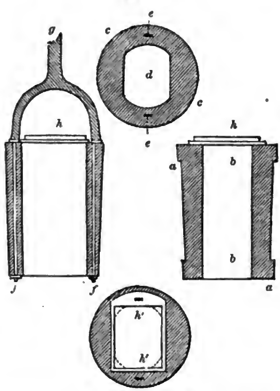


SUCKING OR SUCTION PUMP—SCALE, ¾ INCH TO THE FOOT.

1882. *Suction-Pump.*—In fig. 751 we illustrate a form of the sucking or suction pump; the following is a description of its parts and mode of operation. The pressure of the atmosphere explains the action of the common sucking-pump. The plunger, by its upward movement, withdraws the air from the chamber of the pump, and the air, pressing on the water in the well, causes it to rise and fill the chamber vacated by the air. The air cannot force the water higher than 33.87 feet. The pump-barrel is at *a a*, the water-chamber and cover with exit-pipe at *b b*; *c c* the working handle, vibrating on a stud on the snug *d*; *e* the piston-rod attached to the piston *f*, the valve of which opens upwards; *g* the lower valve, also opening upwards; *h* the pipe leading to the well, the length of which should not, of course, for the reason just given, exceed 33.87 feet. The action of the pump is as follows: Supposing the piston *f* at the bottom of the working-barrel *a a* to be drawn upwards by depressing the outer extremity of the handle *c*, this movement causes the valve *g* to open upwards, through which the action of the ascending piston draws air, which, creating a vacuum, admits of the water being forced by the atmospheric pressure up the tube *h*, and is afterwards "drawn," as the technical term has it, up by the piston *f*; on the piston-rod *e* reaching the top of the working-barrel *a a*, the space between the piston *f* and the valve *g* is filled, or nearly so, with water. On depressing the piston *f*, by raising the outer extremity of the pump-handle *c*, the pressure of the water opens the valve of the piston, and closes the valve *g*; and as the piston descends, the water passes from the lower to the upper side of the piston *f*. On the piston *f* reaching the bottom of its stroke, the water occupies the space in the working-barrel above the piston. On raising the piston *f* by the piston-rod *e* and handle *c*, a double action ensues; the valve of the piston *f* is closed, and the water above it is gradually lifted from the working-barrel *a a*, and passed to the chamber *b b*, from which it flows by the exit-pipe *b*; while this is going on, the valve *g* is opened, and the vacuum beneath the piston being again formed, the water from the well, passing up the tube *h*, follows the piston *f*, and fills—on the piston reaching the upper part of its stroke—the pump-barrel, as before. In the figure the piston *f* is shown in the act of descending.

1883. *Pump-Plunger or Piston.*—In fig. 752 is illustrated the construction of the pump-piston adapted for the form of pump described in last par. The body of the piston *a a* is usually made of elm or beech, and of a slightly conical form. It is provided with a central aperture *b b*, the usual form of which is shown in the section of the piston *c c* at *d*. The body of the plunger is not of uniform thickness, but is partly turned down so as to form a neck or shoulder near each extremity, as shown at *a* and *a*. Round this part a strip of thick leather is wound, the edges of which meet, and are forced in close contact when the piston is inserted in the pump-barrel. The edges should not be sewn together, as is sometimes practised, as this creates bumps and inequalities which materially injure the action of the piston. At either end of the central aperture *d*, an aperture or slot is cut, as at *e e*, extending from top to bottom of the body of the piston. These slots admit of the ends *f f* of the forked extremity of the piston-rod *g* being passed through, and secured by nuts or washers, as shown at *f f*. Before the forks *f f* are thus secured, the valve or flap *h h* is placed on the upper face of the piston, and one of the forks *f* passed through an aperture made in one end of the valve, which by this means is secured to the piston. The flap or valve is usually made of stiff leather, of the form as shown in the lower figure at *h' h'*. The upper end at *h'* is prolonged, and is provided with a slot, through which one of the forks *f* passes as above described. The valve or piece of leather is made larger than the aperture *d*, so that when it is forced downwards it will completely cover the aperture, and lie flat against the surface of the plunger, thus securing a water-tight joint. To facilitate the action of the valve, a thick piece of iron or brass is riveted to the upper side.

Fig. 752.

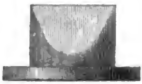


PUMP-PLUNGER OR PISTON—SCALE, 2 INCHES TO THE FOOT.

1884. The lower valve *g*, fig. 751, is constructed much in the same way as that now described. It is fixed firmly at the bottom of the working-barrel, and should be provided with a cross or curved arm similar to that shown at *i*, by which it can be withdrawn from its seat for repair as desired. This is effected by withdrawing the piston, and passing down the barrel an iron rod provided with a hook at one end, which catches the guard *i*, and by pulling at which the valve can be released from its seat.

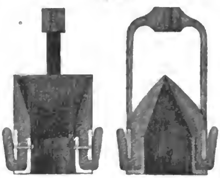
1885. *Perreaux's India-rubber Pump-Valve.*—In fig. 753 we give a sketch of one Perreaux's India-rubber pump-valve, corresponding to the foot-valve *g* in fig. 751, and in fig. 754 section of *bracket or plunger-valves* corresponding to *f* in fig. 751. "These valves are constructed entirely of India-rubber, vulcanised for the purpose, and take the form of a tube flattened at one extremity, something similar to the mouth-piece of a hautboy, and approaching as nearly as possible in form and action the valves contained in the human heart. The thickness of the sides of the upper part diminishes gradually to the top, where the two sides meet and form two lips, which, when the valve is in a state of rest, are in close contact, and prevent the downward passage of the fluid. With any upward pressure the lips freely separate, and allow the upward passage of the fluid. The gradual diminution in thickness or tapering of the sides, forming the lips of the passage, enables the valve to open and close with the slightest variation of pressure, and, by properly proportioning, to resist any required amount of downward pressure. The passage for the fluid is larger in these valves than in any others of equal dimensions; they also possess the advantage of having a 'clear way,' there being nothing whatever to retard the passage or flow of water, and owing to the self-acting principle imparted by the elasticity of the material, they close perfectly and instantaneously the moment the pressure from below ceases. The lips of the valve being flexible and elastic, any foreign substance which may enter the suction-pipe, such as sand, gravel, coal, dust, cinders, grain, cotton, tow, rags, chips of wood, &c., passes freely through without in the least interfering with or deranging the action of the valve. A further advantage they possess is, that, however long the pump may have remained dry, they require no priming, by the application of water, &c., to make them act. The peculiar form of these valves enables them to work equally well in any position, whether vertical or horizontal. The material of which these valves are constructed, perfectly resists the action of acids, alkalies, sea-water, spirits, liquid-manure, ammonia, heat or cold, nor will it suffer from any period of disuse."

Fig. 753.



FRONT ELEVATION OF PERREAUX'S INDIA-RUBBER PUMP-VALVE.

Fig. 754.



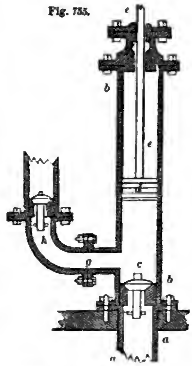
SECTIONS OF BRACKET-VALVE.

1886. *Clarkson's Square Pump.*—A new form of pump for agricultural purposes has been introduced very recently by Mr Clarkson of London, in which the pump, barrel, and piston are of a square form. The piston gives a perfectly clear water-way, and passes with great facility large masses of matter. In this way the inventor claims for it considerable merit as a liquid-manure pump. It seems also well adapted for keeping bog-holes dry while the peat is being cut out of them.

1887. *Force-Pump.* — In the suction-pump there is, as has been already explained, in par. 1882, a limit to which the water can be raised. In the force-pump water can be raised to a very much greater height. The force-pump acts both by the elasticity and the pressure of the air. The pressure causes the water to be lifted to a height not exceeding 33 feet, but the elastic force of the air in the condenser of the force-pump causes the water to rise from it to a very considerable height. It is on this principle that the fire-engine causes the water to rise to the roofs of houses.

1888. The arrangement of the force-pump and its mode of action are illustrated in fig. 755. *a a* is the pipe leading from the well, which must not exceed 34 feet in length; *b b* is the pump-barrel,—where the pipe *a a* joins this, a valve *c* opening upwards is fixed; the piston *d* is solid; *e e*, the piston-rod, works in a stuffing-box *f*; *g* is the side delivery-pipe, furnished with a valve *h* opening upwards. Supposing the piston *d* to be at the bottom of the working-barrel *b b*, and to be drawn upwards, the valve *c* is raised, and the water from the well, passing through the pipe *a a*, follows the piston *d*. On this reaching the top of its stroke, the pump-barrel beneath it is filled with water. On depressing the piston *d*, the pressure of the water closing the valve *c*, it has no other mode of escape than by the side-pipe *g*. As the water passes through this, it presses on the under side of the valve *h*, opens it upwards, and is forced up the pipe *i* to any desired height.

Fig. 755.



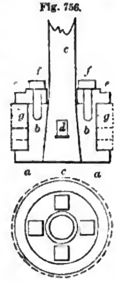
SECTION OF FORCE-PUMP—SCALE, ¾ INCH TO THE FOOT.

1889. The valves *c* and *h* are known as the "conical" form. Their mode of construction will be found in the section on Steam-engines, while describing the "force-pump" of a high-pressure engine.

1890. The solid piston *d*, fig. 755, may be constructed of two discs of metal, adjusted at any position at the extremity of the piston-rod, which is screwed for this purpose, discs of leather, vulcanised India-rubber, felt, or hemp, being firmly secured between them.

1891. Another form of piston is illustrated in fig. 756, where *a a*, *b b*, is the body of the piston, *a a* being a circular flange. The piston-rod *c c* is passed down a central aperture made in *b b*, and secured by a key or cottar *d*. An upper plate *e e* is secured to the body *b b* by the bolts *f f*. Before securing this plate or flange *e e*, the discs or rings of felt or hemp are placed round the body *b b*, as shown by the dotted lines *g g*. On the requisite number of these being placed on, the plate *e e* is then secured, and the piston ready for use. The external diameter of the upper and lower flanges *a a*, *e e*, is a little less than the bore or internal diameter of the working-barrel of the pump; the internal diameter of the rings of felt, &c., *g g*, being equal to the diameter of the body *b b* of the piston; their external diameter equal to, or a little larger than, the bore of the working-barrel, as shown by the dotted circle in the lower figure *c*, which is a plan of upper side of piston.

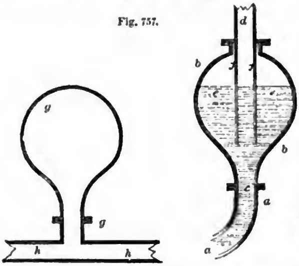
Fig. 756.



FORCE-PUMP PISTON OR PLUNGER, SECTION AND PLAN—SCALE, 3 INCHES TO THE FOOT

1892. In both forms of pump, the suction and the forcing, the flow of water is intermittent, taking place in the suction-pump, fig. 751, while the piston is ascending; and in the force-pump, fig. 755, while the piston is descending. To insure a continuous flow, a contrivance, known as the "air-vessel," is employed in conjunction with force-pumps. This is illustrated in fig. 757, where *a a* represents the side delivery-pipe, corresponding to *g*, fig. 755. To this is attached a hollow vessel *b b*, into which the water is passed through a valve placed at *c*; a pipe *d*, corresponding to *i*, fig. 755, passes down the interior of this, to within a short distance of the valve *c*. The water is generally maintained in the vessel *b b* about the level *e e*, thus keeping a place *f f* filled with compressed air, the elasticity of which forces the water up the pipe *d*.

Fig. 757.

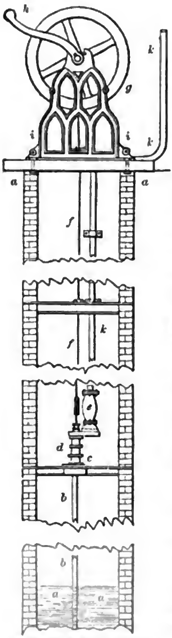


AIR-VESSELS FOR FORCE-PUMPS—SCALE, ½ INCH TO THE FOOT.

1893. From the peculiarity of operation of the force-pump, a loss of power is sustained, equal to, according to M. Morin, from 55 to 80 per cent of the working power. Some of this loss is obviated by using a second air-vessel; this being applied to the suction-pipe immediately below the barrel, as shown in fig. 757, where *g g* is the air-vessel attached to the suction-pipe *h h*, corresponding to *a a*, fig. 755.

1894. *Gwynne's Farm Hand-Pump.*—In fig. 758 we give an arrangement of hand-pump for farm purposes, designed and manufactured by Messrs Gwynne, of Essex Wharf, Strand, London. In this illustration *a a* is the pump-well; *b b* the suction-pipe leading to the platform *c*, to which is secured the *force-pump d*; *e* the air-vessel; *f f* the pump-rod, worked by a crank in the axle or shaft of the fly-wheel *g* turned by the handle *h*. The frame *i i* for supporting the fly-wheel shaft is bolted to the bed-plate covering the mouth of the well. The water is forced up the pipe *k k* from the air-vessel *e*. This pump would be serviceable in a deep well.

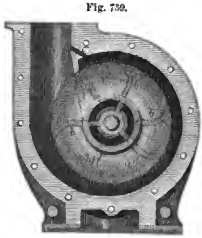
Fig. 758.



GWYNNE'S FARM HAND-PUMP.

1895. *Centrifugal Pump.*—Various forms of pumps have been introduced from time to time to insure a continuous stream. Of these, by far the most efficient and economical is that known as the centrifugal pump by Messrs Gwynne. It is quick in action, small in size for the work it performs, easily applied to work, and has no complicated array of valves and parts, which are liable easily to get out of repair, or become choked by the passage of extraneous matter in the fluid on which it operates. The mechanical details of construction, and the mode of operation, will be understood from the following illustration and description. Fig. 759 is a side-elevation in section of the pump; fig. 760 an end elevation, one side being in section. The hollow rotating disc *a a*, fig. 759, is made fast upon the horizontal shaft *a a*, fig. 760, and works within the case or receiver *b b b b*, fig. 759; arms or impellers, *b*, shown in dotted lines, are placed in the disc. One end of the shaft or spindle *a a*, fig. 760, is supported in a bearing in the end or cover of the pump-case *b b;* the other end passes through a gland and

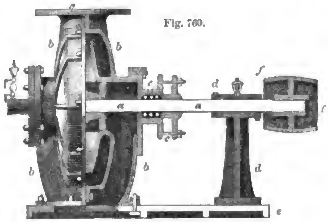
Fig. 759.



SECTION OF GWYNNE'S CENTRIFUGAL PUMP.

stuffing-box *c c* in the opposite cover, and revolves in a standard or bearing *d d*, bolted on to the cast-iron bed-plate *e e*, upon which the pump-case *b b* is made fast. The pulley *f f* is keyed upon the end of the spindle or shaft *a a*; *g* is the discharge-pipe, which may be of any desired length. The suction-pipe *h* may also be placed as desired, and the end is put into the water to be raised, where a foot-valve is placed. When the pump and case are filled with water, and a rapid motion given to the disc by a band on the pulley *f f*, the centrifugal force generated drives the water out of the disc *b* and up the discharge-pipe *g*. Water from the suction-pipe *h* takes the place of that ejected, and so the pump continues to receive and discharge in a continuous stream so long as the velocity is kept up. The quantity of water is regulated by the speed of the disc. The greater the speed, of course, the greater the quantity. The small passage *c*, fig. 759, at the top of the hollow disc *a*, allows any air that may enter the case to get into the discharge-pipe, and to pass away.

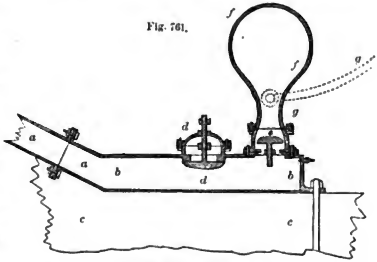
Fig. 760.



END ELEVATION OF GWYNNE'S CENTRIFUGAL PUMP.

1896. *The Hydraulic Ram.*—The hydraulic ram is an exceedingly useful machine for elevating water to a considerable height. It is simple in original construction, has no parts liable to get out of order, and will work continuously for years without repairs after once being put in operation, all that is required being a small stream with a few feet of fall. The machine depends for its operation on the momentum of the falling stream, which, confined in a pipe, is led to a chamber in which valves are placed, and which act as follows: In fig. 761, which is a longitudinal section of a form manufactured by Messrs Gwynne, of Essex Wharf, Strand, London, *a a* is the supply-pipe, which leads the running stream down to the chamber *b b*, bolted to the bed-plate *c c*. A valve *d d* is provided to the chamber *b b*, and which has a tendency to fall from its seat so as to keep the water-way open, till the stream, flowing through the pipe *a a*, acquires sufficient momentum to close it. The velocity of the stream being thus checked, the water raises the valve *e*, which moves the reverse way of the valve *d d*, and enters the air-vessel *f f*, from which it is finally passed by the pipe *g g*, which can be led to any desired elevation above the level of the ram. On the water passing into the air-chamber *f f*, it is pressed upon by the air in the upper part of the vessel, which closes the valve *e*. The momentum of the flowing stream in the pipe *a a* and vessel *b b*, being thus exhausted, the valve *d d* falls, and allows the water to escape from the vessel *b b*, through the valve opening, till the flowing stream again acquires such momentum as to close the valve *d d*. When this happens, the valve *e*

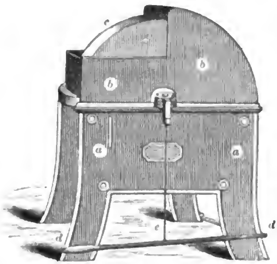
Fig. 761.



SECTION OF HYDRAULIC RAM.

is again opened, and a second quantity of water discharged into the air-vessel *f f*. The action thus described goes on continually, resulting in a regular beating or pulsation of the valves *e*, *d d*, each rising and falling alternately.

Fig. 762.



GRINDSTONE.

1897. The hydraulic ram may be useful in raising water to an elevated cistern, from which it may be led to drive a small turbine placed at the lowest available level.

1898. *The Grindstone.*—In fig. 762 we illustrate a convenient and cleanly form of grindstone, the framing *a a* of which is of cast-iron. The stone is covered with a casing *b b*, leaving part only of the stone exposed, as at *c*. This arrangement prevents the water from being scattered abroad. The revolution of the stone is caused by the action of the foot of the operator on the pedal *d d*, through the medium of the connecting-rod *e* acting on a crank. The form, as here illustrated, is manufactured by Messrs Ibbotson Brothers and Company, of Sheffield, tool-makers.

DIVISION THIRD.—MOVING POWERS OF THE FARM.

1899. Section First.—*Horse-Power.*

1900. *The Horse-Wheel.*—Until of late years the thrashing-machine was in most cases impelled by horses moving in a circular course; and as this power continues to be employed on the smaller class of farms, it is still of that importance to demand being here brought under notice. Horse-wheels are of various construction, as *under-foot* and *over-head;* the former being chiefly used where small powers are required, and the latter where four horses and upwards are employed. In general, in the under-foot wheel, the horses draw by means of trace-chains and swing-tree. In the over-head wheel, of old construction, we also find occasionally the same method of yoking practised; but in all modern over-head wheels the horses draw by a *yoke* descending over their back, from a horizontal beam placed over-head. Custom seems, as usual, to have produced a preference for this mode of yoking, though there appears good reason for calling its propriety in question, especially if the course has a diameter of 22 feet or upwards. The argument in support of the over-head draught is, that the horse exerts his force in the direction of a tangent, or very nearly so, to the curve in which he walks, or at right angles to the beam by which he draws; while, in the swing-tree draught, his shoulders being considerably more in advance of the point of attachment, his exertions must necessarily tend in a direction that will form an angle more acute than a right angle, but which will vary with the radius of the course. It is quite true that this is the case, and that the horse will draw at a disadvantage, to a certain extent, but the amount of this disadvantage is small. In a 26-feet course, which is a good medium, giving the over-head draught the full advantage of the right-angle (90°), the other will draw at an angle of about 72° with the radius or beam; and it is easy to show that the amount of disadvantage arising from this is as 21 to 20. If the draught of a horse in a wheel amounts to 170 lb. under the favourable position, it will require an exertion of 178½ lb. from the same horse, when yoked unfavourably—that is, by a swing-tree. With this disadvantage, which is but small, if we compare the freedom of action and uniformity of the resistance in the case of the swing-tree draught, with the constrained action and jolting effects which the horse undergoes in the over-head yoke—and to these if we add the chances of disadvantage to horses of low stature, being constrained to draw at an unfavourable vertical angle—we shall soon find an amount of disadvantage greater than in the former case. The question is not now of that importance which it once possessed, in consequence of the extensive application of steam; but it appears still to be deserving of consideration.

1901. In the construction of the horse-wheel also, a question arises as to the *diameter of the actual wheel*, whether it should be equal in diameter to the entire horse-walk, and work as a spur-wheel, or have a diameter considerably under the walk, and be applied as a face or bevelled wheel. It appears to us that the *large spur-wheel*, of 25 or 30 feet in diameter, has been conceived under a false impression, and that, on principle, its application is erroneous. It is also probable that a consideration of the overshot water-wheel, which, from its construction, and the nature of the element employed, requires that its power should be given off at or near the extremity of its arms, may have given rise to this formation; but the causes that combine to render this not only advisable, but imperative, in the water-wheel, if everything is duly considered, do not apply to horse-power. When the horse-wheel has a diameter larger than the mean diameter of the horse-path, it gives the first motion a higher velocity than that of the moving power, by its more extended radius; and if any inequality occurs in the moving power, it will sensibly affect the succeeding motions. Horses do not exert a perfectly uniform force when yoked in a wheel; the very act of stepping forth, by removing the exertion from one shoulder to the other, produces small increments and decrements, alternately, to the power, and these must be communicated to the wheel which extends beyond that point of the lever by which the horse draws. Besides this effect on the machine, it must have an equally bad effect upon the horses; for, in consequence of the construction of the large wheel, and from the yoke being applied to a point where all elasticity is removed, the draft becomes what is termed *dead;* that is to say, there are no elastic or yielding parts betwixt the power and the first impulse, that might tend to soften the sudden strains that come upon the horses, unless other means are resorted to, to produce that result. Wheels of this construction will, therefore, be found more fatiguing to the horses than those of smaller diameter.

1902. Of horse-wheels with a *small circle of teeth*, the diameter best suited for all purposes, and which might produce a maximum effect, has not yet been defined; but, from analogy, and taking into view the properties of the centre of percussion, we may infer that the radius of the segments forming the toothed-wheel should be two-thirds of the radius of the beam, measuring to the centre of draught, which may be taken at 11 feet when the course is 26 feet diameter, giving to the toothed segments a diameter of 14 feet 3 inches. The diameter thus found is subject to modification, arising from considerations of strength, and the too great obliquity of the diagonal braces of the wheel, that would follow upon a large diameter. Such considerations will induce a reduction of diameter to 12½ or 13 feet, as a good medium size of wheel. The projection of the horse beams beyond the point of action of the toothed segments, produces that degree of elasticity pointed out in par. 1901, the absence of which forms a defect in wheels of large diameter.

1903. The horse-wheel represented in figs. 1 and 2, Plate XXIX., is constructed on data derived from the foregoing considerations: fig. 1 is an *elevation*, and fig. 2 a *plan* of the wheel, the same letters of reference applying to both figures. It is constructed for four horses, the course is 26 feet diameter within the pillars, and the wheel is 13 feet diameter, with a hollow cast-iron central shaft, having a flange at top and bottom 2 feet diameter, to which the arms and stays of the wheel are bolted. The position of the horse-wheel must be always adjoining to the barn; it may or may not be on the side towards the stackyard, but generally towards it. In the figures, then, the barn-wall is marked *a a*, and the two main pillars, which support the main collar-beam, are marked *b b*, the two minor pillars, erected solely for completing the bearings of the roof are *c c*, and *d d* is the floor or horse-walk. The footstep of the horse-wheel is supported on the stone block *e*, the step being adjustable by four screws, to bring the wheel to the true level; and *f f* is the collar-beam, 12 by 8 inches, which is laid upon and bolted to the main pillars, and carries the plummer-block for the head of the central shaft. The sheers *g g* are 12 by 4 inches, framed into the collar-beam, and resting on the wall *a a*; the dotted lines *h h* represent two diagonal braces to the sheers, to resist the shake from the action of the wheel upon the pinion of the lying shaft; and the cast-iron bridge *i* is bolted down upon the sheers carrying the end of the lying shaft. The flanges of the central shaft *k* and *l* form the foundation of the wheel; to *l* are bolted the horizontal arms *m*, 6 by 2½ inches, as well as the horse-beams *o*, which are 10 by 6 inches, and these are supported by the diagonals *n n*, 4 by 2½ inches, seated in and draw-bolted to the flange *k*. The horizontal braces *p* of the horse-beams are 6 by 2½ inches; they are framed into the ends of the arms *m*, and secured with cast-iron knee-plates at their junction with the wheel and with the horse-beams *o*. The yoke-bars *q q* are made of hardwood, strongly bolted to the horse-beams *o*, and are each mounted with an iron pulley near the lower end, over which the draught-chain passes. The yoke-bars *q* are 6 by 3 inches, and taper towards the lower ends; at the point where the draught-chain passes through them their height from the horse-path should be 3 feet 6 inches, liable to slight variation, arising from the stature of the horse that is to be yoked into it. The wheel *r* is now always made of cast-iron, in segments, and, when the wheel is very carefully made, the segments are fitted and bolted to a bed-plate of the same material, previously bolted to the arms *m* and horse-beams *o*. The breadth of the bed-plate may be 6 inches, with low flanges to keep the segments in place. The toothed segments should be 4 inches in breadth, and their pitch 2 inches, the diameter of the wheel being, as before stated, 13 feet. The horse-wheel pinion *s* is 14¼ inches nearly in diameter, mounted on the lying shaft *s t*, whose inward bearing is upon the barn wall *a a*, in an opening formed for the purpose, and this shaft carries the spur-wheel *u* inside the barn.

1904. The calculations of this machine would stand thus: The horses will walk the course three times in a minute, being at the rate nearly of 2¼ miles per hour; the lying shaft *s t* will make eleven revolutions for one of the wheel, or thirty-three per minute; and the drum pinion, which is driven by the spur-wheel *u*, if made 8.6 inches diameter, the wheel being 7 feet, would give the drum 320 revolutions per minute,—a fair average velocity for a four-horse machine, which can be increased by a quicker step of the horses, say to 2½ miles per hour, which would give 340 revolutions per minute to the drum.

1905. Some horses, when yoked in a wheel, are observed, after a short practice, to take advantage of lagging back, and allowing those who are more willing to take the heavy end of the work. To counteract this, methods have been adopted to make the horses draw by chains, so arranged as to make them work against each other in pairs; or make any number of them draw from a ring-chain common to the whole.

1906. Another method was to make each horse draw against a certain weight suspended over pulleys; but all these have their imperfections in one way or another.

1907. *The Ring-Chain.*—A new and more perfect arrangement of the ring-chain was introduced by Mr Christie, Rhynd, Fifeshire, which received the approbation of the Highland and Agricultural Society of Scotland.* This arrangement is exhibited in fig. 2. The principle of the arrangement is, *that the ring-chain forms a figure of as many equal sides or angles as there are horses in the wheel, and that the angles shall always remain equal.* The arrangement to produce these properties is this: At the points *v v v v* on the horse-beams *o*, are firmly attached the wood or iron pulley-cases, each having two small pulleys moving horizontally; and at the points *w w w w*, four other cases, each having a pulley moving horizontally, and likewise one vertically; each of the vertical ones, with its pulleys, being suspended on a slide-rod of 2 feet in length. At each of the points *v* a loop of the ring-chain is passed through the case betwixt the two pulleys, and is drawn forward till it pass over the horizontal pulley at *w*. The *draught*-chains are now passed each through its own *vertical* pulley in the case *w*, the ends being carried forward and over the leading pulleys at the head of the yoke-trees; they are then led down and passed through the draught-pulleys in *q q*, fig. 1, the chains terminating at *c′ d′*, to which the horses are yoked.

1908. The reeving of the pulleys and chains will be more clearly seen in the perspective views, figs. 3 and 4, Plate XXIX., where the same letters as before are applied. Thus, fig. 3 shows the pulleys and case, as fixed to the horse-beam at *v*, with a part of the beam broken off at both ends, *c′ d′* being parts of two sides of the square formed by the chain, and the double portion *v′* that part of the loop that would join *w* in fig. 4; here the loop passes round the horizontal pulley of *w*, and the portion of chain *a′ b′* in this figure is the loop of the draught-chain passing round the vertical pulley of *w*, and onward to the yoke-trees. In fig. 4 *y* is the slide-rod, and *x* the hook by which the pulley-case is suspended and slides upon *y*.

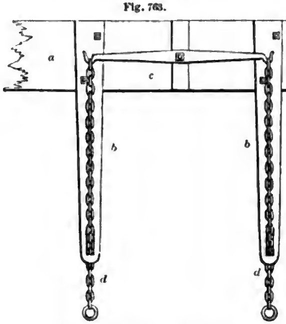
1909. It will be perceived that in this arrangement the primary figure of the chain cannot change, for though one horse pull so much as to go ahead an inch or a foot, some other horse, or perhaps the whole, must have retired in proportion, but the whole effect will be simply to lengthen or shorten these loops, without affecting the fundamental figure; every horse must, therefore, continue to pull an equal portion of the load, without change, unless any one is allowed to bring his pulley *w*, fig. 4, to the end of the slide-rod *y*, a circumstance that can hardly occur. In the usual methods of yoking upon a ring-chain, the chain is only passed over the pulleys *v*, and the horse draws by the pulley, which in these arrangements is movable, the loop of the draught-chain, if double, passing round it, or, if single, is simply hooked to the pulley-case; hence, the primary figure is variable: and suppose that one horse, or two opposite horses, were to slacken their exertions for a few seconds—and a lazy horse will be always disposed to do this—the two other horses must go ahead to tighten the chain, and these motions will produce a figure in the primary chain, having two acute and two obtuse angles, the lazy horses having the obtuse, and the willing horses the acute angles. It were easy to demonstrate, by the resolution of forces, that the two

* *Transactions of the Highland and Agricultural Society*, vol. xii. p. 264.

lazy horses, as long as they continued to pull lightly, would have much less exertion demanded of them to keep the chains in equilibrium than the other two horses, and the forces could only be restored to equality when the angles of the primary figure became again equal. This defect of yoking upon the *catenarian* system does not appear to have attracted the attention of any inquirer, but without knowing why, it seems to have deterred practical men from employing it, for it is now seldom in use; but Mr Christie's method, from the perfection of its principles, is deserving of application.

1910. A method of equalising the resistance to the shoulders of each individual horse has been long practised, and which, from its simplicity, as well as its beneficial effects upon the horses, is deserving of general adoption. The apparatus consists of an iron lever with equal arms, about 30 inches in length, and 2 inches by ½ inch at the centre; this is suspended upon a bolt by a perforation through the centre of the lever forming the fulcrum, and the ends are formed into hooks to which the draft-chains are attached. Fig. 763 represents the application of this to the horse-beam, wherein *a* is a part of the beam, and *b b* the yoke-trees; *c* is the lever above described, suspended upon the back of the horse-beam; *d d* the draught-chains, hooked to the lever, and passed under the pulleys of the yoke-trees, beyond which the horse is yoked to the extremity of the chains. The advantages of this mode of yoking will at once be obvious; for, suppose that, from inadvertence, the horse may have been unequally yoked, whenever he exerts his force, the chain that had been yoked short—suppose it to be the left shoulder—will immediately pull down the end of the lever to which it is hooked, and bring the longer chain to bear with equal resistance upon the right shoulder. The lever will also vibrate at every step taken by the horse, as his efforts are changed at every step from the one shoulder to the other: the lever will therefore tend to equalise his exertions in respect to his muscular economy, and to the motion of the machine.

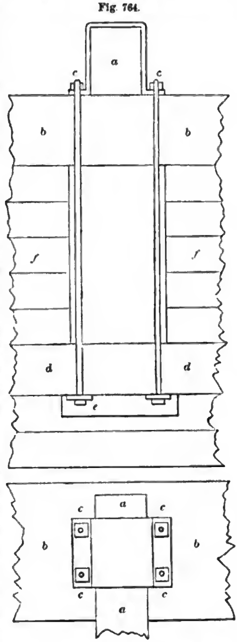
Fig. 763.



THE LEVER FOR EQUALISING DRAUGHT.

1911. It is worthy of remark that the pillars of the shed in which the horse-wheel is placed, being generally of slender dimensions—those which support the collar-beams not exceeding perhaps 8 feet in height, 2 feet in thickness, and 7 feet in breadth—it is found that the action of the horse-wheel has a tendency to shake them, and on the consequent vibration of the collar-beam additional weight is thrown upon the horses to overcome. To obviate this injurious tendency, a method has been adopted in Forfarshire to render the collar-beams more secure. Fig. 764 shows how this is effected: *b b* is a strong block of stone 12 or 15 inches thick, upon which the collar-beam *a* rests. The common practice, which is complained of, is to fasten the beam to this stone by means of a strap of iron, terminating in bolts, which pass through the stone, and are secured under it with nuts. The improvement adopted is to place a cap of cast-iron upon the collar-beam *a*, provided with a flange at each side, having a hole at each corner to permit a bolt *c c* to pass through it and the stone *b b*, to and through the lower block of stone *d d*, into the space below it *e*, where the bolts are screwed fast with nuts. The bolts may be made of any length desired, and the ashlar-work comprised in the entire series of stones *b b*, *d d*, and *f f*, is confined to the interior face of the two pillars which support the collar-beam, and which should be well dressed and jointed together. The lower part of fig. 764 shows a plan of the above arrangement, where *a a* is the end of the collar-beam, *b b* the block of stone, and *c c c c* the flanges and bolt bevels of the cap.

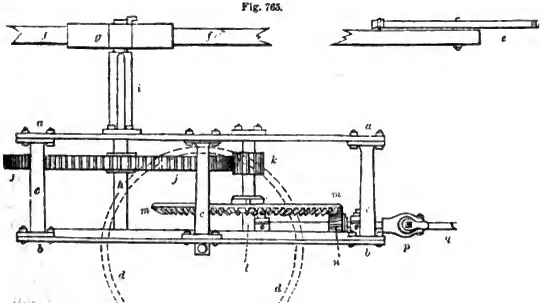
Fig. 764.



MODE OF INSURING STEADINESS IN THE COLLAR-BEAM OF HORSE-WHEELS.

1912. *Dray's Under-foot Horse-Works.*—We now direct our attention to the illustration and description of "under-foot" horse-works. In fig. 765 is given a side elevation, and in fig. 766 a plan, of horse-works manufactured by Messrs Dray & Co., Swan Lane, London, adapted to drive a two-horse-power portable thrashing-machine. The upper frame *a a*, and lower frame *b b*, are connected together by iron pillars *c c c*; the length of the frames being 5 feet 4 inches, the breadth 3 feet 11 inches. The height between the two frames is 17 inches; the diameter of the connecting pillars *c c c* being 2½ inches. The breadth of the side and end pieces of the framing is 6 inches, the thickness being 1¼ inch. The framing *a a*, *b b*, is supported on two wheels *d d*, 3 feet diameter, these being used for convenience of transport. The horses are attached to the whipple-trees *e* bolted to the levers *f f*. The terminations of these are inserted into the cast-iron cup *g* fixed to the end of the vertical shaft *h*, revolving at its lower extremity in a step attached to the lower frame *b b*; and near its upper extremity, in the central bearing of the cross bracket *i*, the shaft *h* carries a spur-wheel *j j*, 3 feet 4 inches in diameter, engaging with a pinion *k*, 5½

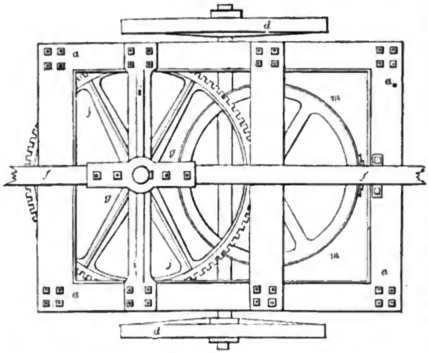
Fig. 765.



SIDE ELEVATION OF DRAY'S HORSE-WORK—SCALE, ½ INCH TO THE FOOT.

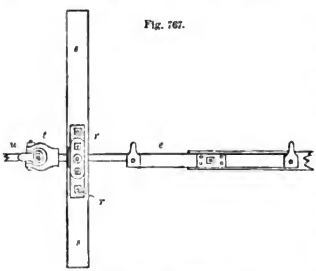
inches diameter. This pinion is keyed on the vertical shaft *l*, the lower part of which carries a bevel-wheel *m m*, 2 feet 9 inches diameter, and which engages with a pinion *n*, 6 inches in diameter. This pinion *n* is keyed on a horizontal shaft revolving in bearings *o o*, keyed to the lower frame *b b*. To the end of the shaft the universal joint *p* is fixed, giving motion to the lying shaft, the opposite extremity of which works in bearings *r r* fixed to the beam *s s*, fig. 767. The length of the shaft *q*, fig. 765 (broken off in the figure to save space) is, from centre to centre of the coupling-joints *p* and *t*, fig. 767, 9 feet. The length of the bearing *s s*, fig. 767, is 3 feet 9 inches, its breadth 4 inches, and thickness 2 inches. The shaft *u* is jointed at one end to the coupling-joint *t*, and at the other to a third coupling-joint attached to the driving-shaft of the machine to be worked. The length of the levers *f f*, fig. 765, from the centre of the cap *g* to the centre of attachment of the whipple-trees *e*, fig. 767, is 10 feet 10 inches.

Fig. 766.



PLAN OF DRAY'S HORSE-WORK—SCALE, ½ INCH TO THE FOOT.

Fig. 767.

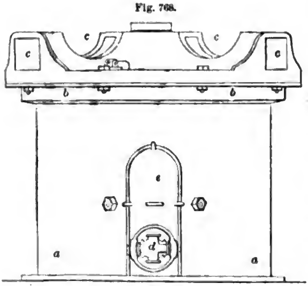


PART PLAN OF DRAY'S HORSE-WORK.

1913. The cost of an apparatus of the form here described for one-horse power is £12; for two-horse, £18, 10s.; for four-horse, £22.

1914. *Barrett, Exall, and Andrews' Safety Horse-Gear.*—From figs. 768 to 771 is a form of horse-work which, from its compactness and excellent arrangement, has obtained a high reputation. It is known as the "safety horse-gear," and is manufactured by the inventors, Messrs Barrett, Exall, & Andrews, of Reading. In fig. 768 we give a side elevation, in fig. 769 a vertical section, in fig. 770 a plan of top, and in fig. 771 a sectional plan, showing the working-gear. The working parts are completely enclosed in a cast-iron case *a a*, fig. 768, so that no

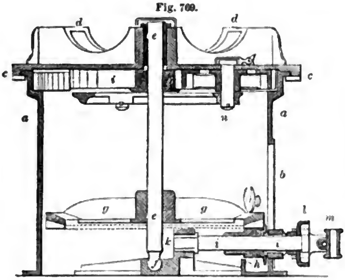
Fig. 768.



SIDE ELEVATION OF SAFETY HORSE-GEAR—SCALE, ¾ INCH TO THE FOOT.

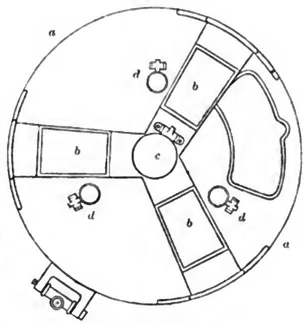
extraneous matter can gain admittance. The cap *b b* contains three sockets or eyes *c c c c*, as shown also at *b b b* in fig. 770, in which are inserted the ends of the driving-levers, to which the horses are yoked with whipple-trees. A door

Fig. 769.



SECTION OF SAFETY HORSE-GEAR—SCALE, ¾ INCH TO THE FOOT.

Fig. 770.

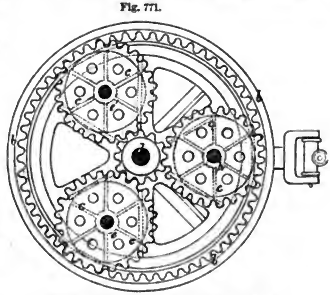


PLAN OF TOP OF SAFETY HORSE-GEAR.

or trap, *e*, fig. 768, can be taken off when required, to gain admittance to oil the lower bearings. The power is taken off by the lying-shaft through the coupling-joint *d*.

1915. The driving-gear is shown more particularly in the section, fig. 769. The outer casing is shown at *a a*, *b* the door or trap. The cap *c c* revolves easily on the top of the casing; two of the sockets for connecting the driving-levers with the cap are shown at *d d*. The cap *c c* is keyed to a vertical shaft *e e*, the foot-step of which is at *f*. This shaft carries a bevel-wheel *g g*, engaging with a bevel-pinion *h h*, keyed on a horizontal shaft *i i*, revolving in bearings *k k*, connected with the lower part of the casing *a a*. The universal joint *l m* is attached to the outer extremity of the shaft *i i*. The method in which motion is given to the shaft *e e* will be explained by reference to fig. 771. The revolving cap *c c*, fig. 769, carries three studs, of which one is shown at *n*, and the relative position of which is shown at *d d d* in fig. 770. These studs carry small pinions, *c c c*, fig. 771, which engage at once with a pinion *d*, fixed in the vertical shaft *e e* in fig. 769, and with an internal wheel, *b b b*, fig. 771, cast in the upper part of the outer casing *a a a*, fig. 769. Supposing there are sixty teeth in the internal wheel *b b b*, and twenty in the spur-wheel *c*, fig. 771, for each time the spur-wheel *c* is made to travel round the wheel *b b b*, the spur-wheel *c* will revolve three times; and supposing the pinion *d* on the vertical shaft to have half of the number of teeth of the wheel *c*, for each revolution of *c* it will have

Fig. 771.



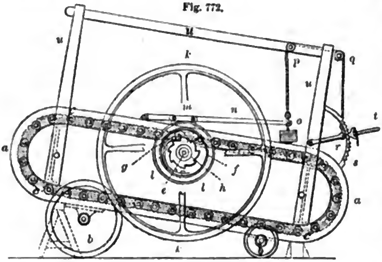
HORIZONTAL SECTION OF SAFETY HORSE-GEAR.

two revolutions. Thus, for one revolution of the cap there will be six revolutions of the wheel *d*. Then supposing the bevel-wheel *g g*, fig. 769, to be five times the diameter of the pinion *h*, for each revolution of the shaft *e e* the shaft *i i* will revolve five times. Suppose, further, the horses to make the cap *c c*, fig. 769, revolve three times per minute, the wheels *c c c*, fig. 771, will make nine revolutions, the pinion *d*, fig. 771, and wheel *g g*, fig. 769, eighteen times, and the shaft *i i* and pinion *h* ninety times per minute. In fig. 770, which is a plan of the cap, *a a* is the outer case, *b b b* three sockets to receive the ends of the driving-levers, *c* a movable cap which covers the end of the vertical shaft *e e*, fig. 769, and *e e' h* similar caps for the shafts of the three pinions *c c c*, fig. 771. These can be lifted up when the bearings require to be oiled, and when closed, prevent the ingress of dust, &c. Three sets of wheels, *c c c*, fig. 771, are given, which tend to equalise the motion.

1916. *Hartas's Inclined-Plane Horse-Work.*—A modification of the American horse-works, on the principle of the treadmill, the horse working on a movable inclined plane or endless platform, has been lately introduced into England, and, to judge from the reports of competent engineers, with some prospect of being a useful addition to agricultural mechanism.

1917. The old form of this mechanism, which, for dogs as well as horses, is much used in America, is open to several objections. "Among others, it has been found that, if the horse is suddenly stopped, either the mechanism becomes deranged by some undue strain thereon, owing to the exertion of the horse to stop the machine (which will continue in action for a short time by the momentum gained by the fly-wheel), or there will be great liability for the horse to be thrown down and injured." To obviate these objections is the object of the patented improvements of Mr Isaac Hartas of Wrelton Hall, Yorkshire, and of which we now offer a brief description. In fig. 772 is given a side elevation of the machine—*a a* the framework, supported on two wheels, *b b*. The travelling-floor *c c*, or inclined endless platform in which the horse walks, consists of a narrow gangway formed by a succession of cross boards, connected by pitch-chains working over rollers at the end of the framework. The platform is furnished with small pulleys or rollers, which run on rails at the side of the machine, and is provided with a flexible toothed rack on its under side. This rack engages with a toothed wheel keyed on the central shaft *e*. To the shaft *e* a cylindrical case or box *f* is also firmly secured; this carries in its interior a point or click *g*, which is kept in contact with the face of the teeth of the ratchet-wheel *h* by means of a spring. The ratchet-wheel *h* is keyed to a hollow shaft which revolves loosely in the central shaft *e*; the hollow shaft carries the fly-wheel *k k*. To the opposite end of the central shaft *e*, on which the box *h* is keyed, a friction-wheel *l l* is keyed. This is acted on by the friction-block *m*, secured to the under side of the lever *n*. This lever is provided at its further extremity with a weight *o*, and a cord *p*; this passes over pulleys *p q*, fixed to the side-framing

Fig. 772.



SIDE ELEVATION OF HARTAS'S HORSE-WORKS

of the machine, and is connected at its extremity with the eye *r* of the lever *r t*, this lever being maintained in any desired position by the curved ratchet-bracket *s*. The side-framing, which confines the horse while working, is shown at *u u*.

1918. The action of the mechanism thus described is as follows: The horse's head being confined to the head-rail of the side-framing *u u*, the attendant eases the friction-brake *m* by depressing the handle *r t*, and lifting the weight *o* of the lever *n*; and as the travelling-floor *c c* is considerably inclined in front, the weight of the horse sets it in motion, which prompts him to commence walking, a continuation of which keeps the platform in motion. The rack of the platform *c c*, engaging with the toothed wheel in the central shaft *e*, gives motion to the cylindrical case or box *f*, and its attached pawl or click *g*. This, taking into the teeth of the ratchet-wheel *h*, gives revolution to the hollow shaft in which it is fixed, and to the fly-wheel *k k*. When the horse ceases to walk, the motion of the fly-wheel is not suddenly arrested, as in the old forms of this machine; for although the motion of the platform *c c*, and cylindrical case *f*, ceases with the motion of the platform, as the fly-wheel *k k* is keyed to the hollow shaft which revolves loosely in the central shaft *e*, it continues to revolve without affecting the other parts of the mechanism. With the revolution of the fly-wheel, that of the ratchet-wheel *h* also continues; but as the motion of the cylindrical box *f* has ceased, the only result is that the end of click or point *g* passes freely over the face of the teeth of the ratchet-wheel *h*. Power is taken to the machine, which it is desired to work through the medium of a driving-belt passing through a drum fixed to the end of the central shaft *e*, next to the friction-wheel *l l*.

1919. It may be useful here to append the report of Mr Amos, Consulting Engineer to the Royal Agricultural Society of England, who instituted several experiments with a view to ascertain the effective power of this machine as compared with a horse-power in which the horses walked round a circle in the usual way. "In the first experiment, one of Richmond and Chandler's oat-crushers or linseed-mills was attached to the horse-works, with a dynamometer intervening to record the work done. The horse, walking at the rate of 2.04 miles per hour, did work equivalent to the raising of 33,110 lb. 1 foot high per minute. During this experiment, at the rate the horse walked, and taking into consideration the angle of elevation of the platform, the horse would have raised himself to the height of 33.66 feet in one minute—that is, had the platform been stationary, and prolonged indefinitely. The horse with his harness weighing 1084.5 lb., and this multiplied by 33.66 feet, the height the horse would have raised himself, equals 36,504 lb. lifted 1 foot high per minute. In the second experiment, the horse walked 1.7 mile per hour, and did work, as shown by the dynamometer, equivalent to raising 31,350 lb. 1 foot high per minute, during which time he would have climbed 28.21 feet, which is equivalent to the raising of 30,594 lb. 1 foot high per minute. In this experiment, the horse walked and worked exceedingly steadily, and the work he did at that time (31,350 lb. lifted 1 foot per minute) fairly represented the work a horse can do by this machine. To compare the above with a common horse-work, the horse used in the last experiment was yoked with another, of similar power and quality, to a two-horse-power works, made by Mr John Barker, of Dunnington. The power was applied to the same mill and dynamometer, and the work done by each horse was equivalent to 26,500 lb. lifted 1 foot high per minute, being about 16 per cent less than the duty done by Mr Hartas's horse-works."

1920. The price of Mr Hartas's machine for one-horse-power is £23, delivered in London; delivered in York, £18, 18s.

1921. SECTION SECOND.—*Water-Power.*

1922. *The Water-wheel.*—Water, when it can be commanded, is the cheapest and most uniform of all powers; and on many farms it might be commanded by carefully collecting and storing in a dam. Water-wheels have been commonly treated as of three kinds, but, with great deference, we conceive they may be classed under two heads. The *under-shot*, or *open float-board* wheel, which can only be advantageously employed where the supply of water is considerable and the fall low; it can therefore rarely answer for farm purposes, and need not be discussed. The second is the *bucket*-wheel, which may be *over-shot* or *breast*, according to the height of the fall. It is this wheel that is adopted in all cases where water is scarce or valuable, and the fall amounting to 6 or 7 feet or more, though it is sometimes employed with even less fall than 6 feet. It is the most effective mode of employing water, except where the fall is excessively high, or exceeding 50 feet, when, in such cases, it is applied to motive machines that are becoming much employed for agricultural purposes—such as the turbine and the vortex wheel, which we shall hereafter describe.

1923. When it is proposed to employ a stream of water for the purpose of power, the first step is to determine the *quantity delivered by the stream in a given time:* this, if the stream is not large, is easily accomplished by an actual measurement of the discharge, and is done by damming up the stream to a small height, say 1 or 2 feet, giving time to collect, so as to send the full discharge through a shoot, from which it is received into a vessel of any known capacity, the precise time that is required to fill it being carefully noted. This will give a correct measure of the water that could be delivered constantly for any purpose: if in too small a quantity to be serviceable at all times, the result may be found by a calculation of the time required to fill a dam of such dimensions as might serve to drive a thrashing-machine for any required number of hours.

1924. If the discharge of the stream is more than could be received into any moderately-sized vessel, a near approximation may be made to the amount of discharge by the following method: Select a part of its course, where the bottom and sides are tolerably even, for a distance of 50 or 100 feet; ascertain the velocity with which it runs through this space, or any measured portion of it, by floating light substances on its surface, noting the time required for the substance to pass over the length of the space. A section of the stream is then to be taken, to determine the number of superficial feet or inches of sectional area that is flowing along the channel, and this, multiplied into five-sixths of the velocity of the stream, will give a tolerable approximation to the true quantity of discharge—$\frac{5}{6}$ of the surface velocity, at the middle of the stream, being very nearly the mean velocity of the entire section. Suppose the substance floated upon the surface of the stream passed over a distance of 100 feet in 20 seconds, and that the stream is 3 feet broad, with an average depth of 4 inches, here the area of the section being exactly 1 foot, and the velocity being 100 feet in 20 seconds, gives 300 feet per minute, less $\frac{1}{6} = 250$ feet, and this, multiplied by the sectional area in feet, or 1 foot, is 250 cubic feet per minute for the discharge. It is to be kept in mind that this is only an approximation, but it is simple, and from repeated experiments we have found it to come near the truth.

1925. For those who wish to go more elaborately into the subject, we may here state a formula derived from Sir John Leslie, for finding the mean velocity, and, having also the transverse section, to find the discharge of a stream or river.

Multiply the *constant* 1.6 into the hydraulic depth and into the slope of the surface of the water per mile, the square root of the product will give the *mean velocity* of the stream in feet per second; and the root, multiplied by the section of the stream in square feet, is the discharge per second. The *hydraulic depth* is the transverse section of the stream in square feet, divided by the periphery of the stream, less the surface breadth.

Example.—If the surface breadth be 3 feet, the bottom breadth $2\frac{1}{2}$ feet, and the slope of the sides each 9 inches, a transverse section of these dimensions will contain 2 square feet nearly, which, divided by the periphery, which is

$$3 + .75 + .75 + 2.5 = 7, \text{ the periphery,}$$

then the area of the section = 2 feet;

$$\text{put } 2 \div (7 - 3) = .5 = 6 \text{ inches, the hydraulic depth.}$$

And suppose the slope at the place of section to be $1\frac{1}{2}$ inch on 100 feet, or 6.5 feet per mile, apply the formula—

$$\sqrt{1.6 \times .5 \times 6.5} = 2.3 \text{ feet, the velocity per second, nearly,}$$

and the delivery will be $2.3 \times 2 \times 60 = 276$ cubic feet per minute.

1926. The next step is to ascertain by levelling from the most convenient point at which the stream can be taken off, to the site where the water-wheel can be set down, and to that point in the continuation of the stream where the water can be discharged from the wheel, or what is called the outfall of the tail-race. If the water has to be conveyed to any considerable distance from the point where it is diverted from the stream to the wheel, a lead must be formed for it which should have a fall of not less than $1\frac{1}{2}$ inch in 100 feet, and this is to be deducted from the entire fall. Suppose, after this deduction, the clear fall to be 12 feet, and that the water is to be received on a bucket-wheel whose power shall be equal to four horses,

The rule for finding the power due to a stream of water whose discharge is already known is, multiply the discharge in cubic feet, per minute, by the height of the fall, and again by 62.5—the lb. weight of a cubic foot of water—dividing by 44,000, gives the number of horse-power.

In the present case, having the height of the fall given and the power wanted, we have the question in this form,

$$\frac{44{,}000 \times 4}{62.5 \times 12} = 234 \text{ cubic feet;}$$

the quantity of water required per minute to produce four horses' power.

If the stream does not produce this quantity, a dam must be formed by embanking or otherwise, to contain such quantity as will supply the wheel for three or six hours, or such period as may be thought necessary. The quantity required for the wheel here supposed, for three hours, would be 42,120 cubic feet; but suppose the stream to supply one-fourth part of this, the remainder, or 31,590 feet, must be provided for in a dam, which, to contain this, at a depth not exceeding 4 feet, would be 88 feet square. But the constant supply of water is often much smaller than here supposed, and in such cases the dam must be proportionally large.

1927. *The Dam.*—The dam may either be formed upon the course of the stream, by a stone-weir thrown across it, and proper sluices formed at one side to lead off the water when required, or, what is much better, the stream may be diverted from its course by a low weir into an intermediate dam, which may be formed by digging and embankments of earth, furnished with sluice and waste-weir, and from this the lead to the wheel would be formed. The small weir on the stream, while it served to divert the water, when required, through a sluice to the dam, would in time of floods pass the water over the weir, the regulating sluice being shut to prevent flooding the dam. This last method of forming the dam is generally the most economical and convenient, besides avoiding the risk which attends a heavy weir upon a stream that may be subject to floods. When water is collected from drains or springs, it is received into a dam formed in any convenient situation, and which must also be furnished with a waste-weir to pass off flood-waters, besides the ordinary sluice.

1928. *The Bucket Water-Wheel.*—The water-wheel should be on the *bucket* principle, and, for a fall such as we have supposed, should not be less than 14 feet diameter; the water, therefore, would be received on the breast of the wheel. Its circumference, with a diameter of 14 feet, will be $3.1416 \times 14 = 44$ feet; its velocity, at 5 feet per second, is $44 \times 5 = 220$ feet a minute; and 234 cubic feet, per minute (par. 1926), of water spread over this, gives a sectional area for the water laid upon the wheel of $\frac{234}{220} = 1.6$ feet; but as the buckets should not be more than half filled, this area is to be doubled $= 2.12$ feet; and as the breadth of the wheel may be restricted to 3 feet, then $\frac{2.12}{3} = .704$ foot is the depth of the shrouding, equal to $8\frac{1}{2}$ inches nearly, and if the wheel is to have a wooden soling, 1 inch should be added to this depth already found, making $9\frac{1}{2}$ inches.

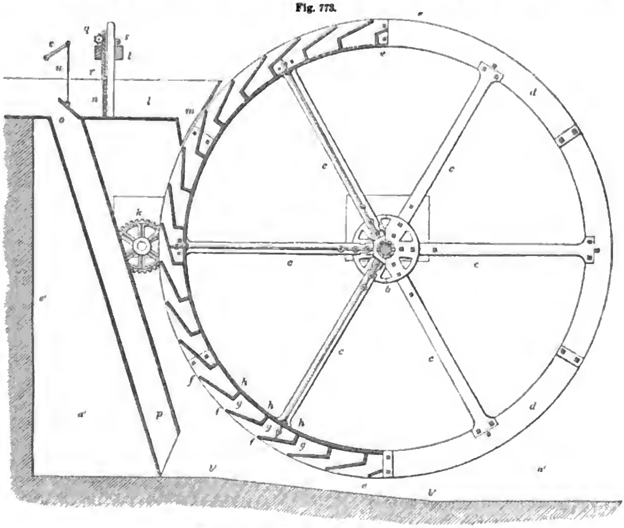
1929. The *ark or race* in which the wheel is to be placed, must have a width sufficient to receive the wheel with the toothed segments attached to the side of the shrouding. For a bucket-wheel it is not necessary that it be built in the arc of a circle, but simply a square chamber; one side of it being formed by the wall of the barn, the other by a wall of solid masonry, at least $2\frac{1}{2}$ feet thick; one end also is built up solid, while the opposite end, towards the tail-race, is either left entirely open, or if the water is to be carried away by a tunnel, the water-way is arched over, and the space above levelled in with earth. It is requisite that the wheel-race here described should be built of square-dressed stones, not common ashlar, but having a breadth of bed not less than 12 inches, laid flush in mortar, and pointed with Roman cement.

1930. Fig. 773 exhibits a *sectional elevation* of the wheel, representing one-half of the wheel in section, the other in elevation: *a′ a′* is the barn-wall, *b′ b′* is the sole of the ark *c′* or chamber, formed of solid ashlar-stone, having an increased slope immediately under the wheel, to clear it speedily of water.

1931. In fig. 774 the plan is represented of dimensions agreeing to the supposed case in par. 1929: *a a* is the wall of the barn, *b′ b′* the outward wall, and *c* the end of the ark; a recess *d* being formed in the wall *a a* for the bearing of the water-wheel shaft *e*.

1932. The shaft, the arms, and shrouding, fig. 773, are all of cast-iron, the buckets and sole being of wood; and to prevent risk of fracture, the arms are cast separate from the shrouding. The width of the wheel being 3 feet, the toothed segments 4 inches broad, and they being 1 inch clear of the shrouding, gives a breadth over all of 3 feet 5 inches, and, when in the race, there should be at least 1 inch of clear space on each side, free of the walls. The shaft *e*, fig. 774, is not required to be longer than just to pass through the bearings, for in wheels of this kind it is improper to take any motion directly from the shaft. The eye-flanges *b*, fig. 773, 2 feet diameter, are separate castings, to which the arms *c* are bolted; the flanges being first keyed firmly upon the shaft. The shrouding *d d* is cast in segments, and bolted to the arms and to each other at

Fig. 773.

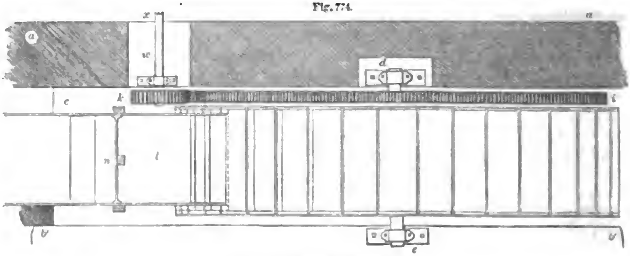


THE SECTION AND ELEVATION OF A BUCKET WATER-WHEEL.

their joinings. On the inside of the shroud-plates are formed the grooves for securing the ends of the buckets and of the sole-boarding, in the form as shown in the section from *e* to *e*. The form of the buckets should be such as to afford the greatest possible space for water, at the greatest possible distance from the centre of the wheel, with sufficient space for the entrance of the water and displacement of the air. In discharging the water from the wheel also, the buckets should retain the water to the lowest possible point. These conditions are attained by making the pitch *f f f* of the buckets, or their distance from lip to lip, $1\frac{1}{2}$ time the depth of the shrouding; the depth of the front of the bucket *f g* inside, equal to the pitch; and the breadth of the bottom *g h* as great as can be attained consistently with free access of the water to the bucket immediately preceding; this breadth, inside, should not exceed $\frac{3}{8}$ of the depth of the shrouding.

1933. The *shrouding plates* are bolted upon the buckets and soling by bolts passing from side to side; and in order to prevent resiliance in the wheel, the arms are supported with diagonal braces. The toothed segments *i*, fig. 774, are bolted to the side of the shrouding through palms cast upon them for that purpose, and the true position of these segments requires that their pitch-line should coincide with the circle of gyration of the wheel; when so placed, the resistance to

Fig. 774.



PLAN OF A BUCKET WATER-WHEEL.

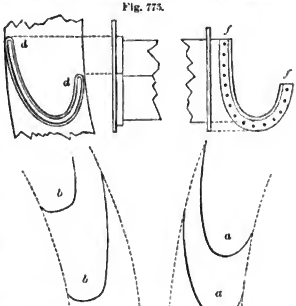
the wheel's action is made to bear upon its parts, without any undue tendency to cross strains. For that reason it is improper to place the pitch-line beyond the circle of gyration, which is frequently done, even upon the periphery of the water-wheel. The determination of the true place of the circle of gyration is too abstruse to be introduced here; nor is it necessary to be so minute in the small wheels to which our attention is chiefly directed; suffice it for the present purpose to state, that the pitch-line of the segment wheel should fall between $\frac{1}{2}$ and $\frac{2}{5}$ of the breadth of the shrouding, from the extreme edge of the wheel.

1934. Another important point is that *where the power is taken off from the wheel;* that is, the placing of the pinion *k*, fig. 774. The most advantageous part for placing this pinion is in a line horizontal to the axis of the water-wheel; here the whole weight of the water acts in impelling the pinion, while no strain is brought on the shaft beyond the natural weight of the wheel. In every position *above* this, unnecessary strains are brought upon the shaft and other parts of the wheel, and these increase with the distance from the first point *k*, till, if placed at the opposite point horizontal to the axis, the load upon the shaft would be *double* the weight of all the water upon the wheel, over and above the weight of the wheel itself.

1935. *Laying the water upon the wheel* is another point of some consequence; but whether it be delivered over the crown of the wheel, or at any point below that, the water should be allowed to fall through such a space as will give it a velocity equal to that of the periphery of the wheel when in full work. Thus, if the wheel move at the rate of 5 feet per second, the water must fall upon it through a space of not less than .4 foot; for, by the laws of falling bodies, the velocities acquired are as the times and whole spaces fallen through, as the squares of the time. Thus the velocity acquired in 1″ being 32 feet, a velocity of 5 feet will be acquired by falling .156″; for 32 : 1″::5 : .156″, and $1''^2$: 16 :: $.156''^2$:.4 foot, the fall to produce a velocity of 5 feet. But this being the minimum, the fall from the trough to the wheel may be made double this result, or about 10 inches. The trough which delivers the water upon the wheel should be at least 6 inches less in breadth than the wheel, to give space for the air escaping from the buckets, and to prevent the water dashing over at the sides; *l*, figs. 773, 774, is the trough, and *m*, fig. 773, the spout that conveys the water to the wheel. It is convenient to have a regulating sluice *n*, figs. 773, 774, that serves to give more or less water to the wheel; and this is worked by a small shaft passing to the inside of the barn. The shaft carries a pinion *q*, fig. 773, working the rack of sluice-stem *r*, a small friction-roller *s* being placed in proper bearings on the cross-head *t* of the sluice-frame; and this apparatus is worked inside the barn by means of a lever-handle upon the shaft of the pinion *q*. As a waste-sluice, the most convenient and simple, in a mill of this kind, is the trap-sluice *o*, which is simply a board hinged in the sole of the trough, and opening from the wheel; it is made to shut close down to the level of the sole, and when so shut, the water passes freely over it to the wheel. The lifting of this sluice is effected by means of the connecting-rod *u* and crank-lever *v*, the latter being fixed upon another small shaft, which passes through the wall to the interior of the barn, where it is worked in the same manner as the regulating-sluice *n*. When it is found necessary to set the wheel, the trap is lifted, and the whole supply of water falls through the shoot *o p*, leading it to the bottom of the wheel-race *b′ b′*, by which it runs off, until the sluice at the dam can be shut, which stops further supply. The wheel here described, if it moves at the rate of 5 feet per second, will make $6\frac{3}{4}$ revolutions per minute. The pinion-shaft *w*, fig. 774, will carry a spur-wheel at *x*, by which all the other parts of the machine can be put in motion. The rate of the spur-wheel at *x* depends on the relation of the water-wheel and its pinion. In the present case they are in the proportion of 8 to 1, and, as the water-wheel makes $6\frac{3}{4}$ revolutions per minute, this, multiplied by 8, will give 54 to the spur-wheel.

1936. *Ventilating Buckets.*—Water-wheels, with wooden buckets of the form in fig. 773, labour under great disadvantages while working in "back-water," that is, when the river is flooded, and the water rises against the wheel. When this is the case, the wheel is not only resisted by the direct pressure of the water, but the rising buckets lift a great deal of water—in some cases they are nearly filled—and cannot be relieved till the bucket clears the water. In other cases less water is taken up, but the bucket contains air, which rarifies, and is the cause of some water being dragged up. But even where no loss arises from back-water, in descending, the bucket is prevented from receiving the water freely, from the contained air having a difficulty in escaping. All inconveniences arising from these defects are now obviated by using the ventilating buckets, the object of which is to admit of the escape of the air while the bucket is receiving its load, and, on the other hand, to admit of its easy readmission while being emptied of its load. The general substitution of iron for wood has also enabled great improvements to be effected in the form and mode of setting of the buckets, these being generally curved, as at *a a*, *b b*, in fig. 775. The curved bucket has been adopted, as it enables the water to be longer retained, which adds so much to the power of the wheel. The sooner the water is discharged, the greater the loss. This loss decreases with the increase of the size of the wheel. When the bucket is of cast-iron, the ends are inserted in grooves of corresponding curve cast in the shrouding, as *d d*, fig. 775. When the buckets and the shrouding are both of

Fig. 775.

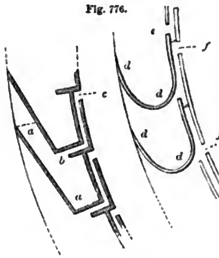


VENTILATING BUCKETS.

wrought iron—the most satisfactory material which can be employed—the ends of the buckets should be turned up at right angles, as at *f f*, to admit of rivet-holes being punched in them, by which they can be fastened to the shrouding. In designing these curved buckets, the object in view should be to obtain a form which, while it retains the water as long as it can act on the wheel, should admit the water freely while the bucket is receiving its load, and discharge it easily when its work is performed. Mr Fairbairn recommends the proportion as under to be followed for wheels for high and for low falls: For high falls, the proportion of opening of the bucket to the contents should be as 5 to 24—that is, for a bucket containing 24 cubic feet, the area of the opening of the bucket should be 5 square feet. For low falls the proportion should be as 1 to 3, or 8 to 24. The breadth of the shrouding *d d*, fig. 773, should be for these proportions three times the width of the opening of the bucket.

1937. *Principle of the Ventilating Buckets.*—The principle of the ventilating buckets is illustrated in fig. 776. As the water enters at *a a*, the air is forced through the passage *b*, and out at *c*, on to the interior of the wheel. Another method is also shown in fig. 776. On this the tail of the bucket *d d* is turned up as at *d e*, leaving a space between it and the back of the sole-plate *f f*, the tail terminating within a short distance of the bucket above. As the water enters, the air is driven through the aperture *e* to the bucket above. On discharging the load, the air enters the bucket at *f f*, and, passing down the channel, issues into the bucket and facilitates the discharge of the water. The advantages gained by this method of construction will amply repay the additional cost which it will incur. In a case in practice, where, before the ventilating buckets were added, the buckets acted as water-blasts and forced the water a considerable distance up in the air, after they were fitted the buckets filled and emptied rapidly, and a gain of 25 per cent of power was obtained.

Fig. 776.



VENTILATING BUCKETS.

1938. *The Turbine.*—A new water-motor—the turbine—has, within the last few years, been introduced into use in this country. It has long been successfully adopted on the Continent and in America; and, possessing many advantages which peculiarly fit it for agricultural purposes, it is deserving of attention. It is applicable to falls of water either too high or too low for an ordinary water-wheel to be erected; and from the shaft being vertical, and the velocity of the wheel being with high falls very great, power can be at once taken from it without the intervention of intermediate gearing. Turbines may be sunk in back-water to a considerable depth without any material loss of power. In cases where the fall is great, although the supply may be small, the height through which the water descends compensates for its small bulk, and a very small machine may give power sufficient to work a thrashing-machine, chaff-cutters, &c. The low-pressure turbines give good results with even so low a fall as 9 inches.

1939. The elementary principle of action of the turbine is to be found in that contrivance known as Barker's centrifugal mill, which is figured in nearly every work on Natural Philosophy, and which is doubtless familiar to all of our readers. This contrivance, it may be here stated, consists of two horizontal tubes attached near the foot to the opposite sides, and communicating with the interior of a vertical pipe, the foot of which revolves in a pivot, and the upper part in bearings attached to the framework of the machine. The whole resembles the letter T inverted—thus, ⊥. The horizontal arms are closed at their outer extremities, but are provided with apertures at the sides near each end, and so placed that they are on opposite sides of the tube. The upper extremity of the vertical tube is provided with a funnel-shaped termination, into which is kept flowing a stream of water, which keeps the vertical pipe continually full. The water issues from the opposite holes in a horizontal direction, causing the arms to revolve with a velocity nearly equal to the flow of the water through the apertures. The force exerted is in proportion to the pressure of the column of water in the vertical pipe, and to the area of the apertures in the horizontal arms. While the lateral pressure is exerting its full force on the opposite side of the arm, there is no solid body at the other aperture on which the lateral pressure can be exerted. This gives one unbalanced pressure, which, according to Dr Robison, is "equal to the weight of a column having the orifice for its base, and twice the depth under the surface of the water in the trunk for its height. If the orifice were closed, the pressure upon it would equal the weight of a column reaching to the surface; but when open, the water issues with a velocity nearly equal to that acquired by falling from the surface; and the quantity of motion which is produced is that of a column twice this length moving with this velocity. The revolution of the machine causes the water—which, having descended the vertical pipe, moves along the arms—to partake of the circular motion, thus producing a centrifugal force that is exerted against the ends of the arms of the machine. According to the laws of motion, this force increases in proportion to the square of the distance from the centre at which it is developed. Thus the velocity of the efflux is increased, and also the velocity of the revolution. But as the circular motion has to be imparted to every particle of water as it enters the horizontal arm, which is done at the expense of the motion already acquired by the arm, there is a limit to the velocity even of an unloaded machine."

1940. In 1775, M. Mathon de la Cour proposed a modification of Barker's centrifugal mill, just described, in which a pipe was brought down from an elevated reservoir, and bent upwards at its lower extremity, to which was attached a short pipe with two horizontal arms.

1941. A modification of this plan, by which any depth of fall was rendered available, was patented by Mr Whitelaw of Paisley, who published an account of his experiments with it, in 1845. The horizontal arms were bent somewhat like the letter S, the curve being that of an Archimedean spiral. The depth of the arms was at every point the same, but the breadth increased towards the centre. This enabled them to contain a quantity of water at any one point inversely proportionate to the velocity at that point, thus making as much of the centrifugal force available as possible. From wheels on this principle Mr Whitelaw obtained nearly 73 per cent of the power employed.

1942. The invention of the turbine is due to M. Fourneyron, who erected the first example at Pont sur l'Ognon, in 1837. The success of this was so decided that, although prejudice, as usual, for a long time prevented its speedy adoption, the attention of practical men was directed to the principle of operation; and in process of time it was adopted very extensively both on the Continent and in America. In its usual form the revolving wheel is placed horizontally, and is provided with a series of curved buckets or channels. Within this revolving wheel a fixed circular disc is placed, provided with a series of curved guides. This disc or platform is secured to a vertical pipe or cylindrical chamber;

this is stationary, and hollow, the moving shaft of the revolving wheel passing upwards through it. The water enters at the centre of the disc or platform, passes simultaneously through all the curved guides, and, diverging from the centre, enters all the curved buckets of the wheel, and escapes at the outer orifices in the periphery or circumference of the wheel. A cylindrical sluice is used to regulate the admission of water from the central guides of the disc or platform to the curved buckets of the wheel. This sluice is in the form of a hoop, the inner diameter of which is equal to the circle formed by the inner extremities of the curved guides in the fixed platform; the under side of the hoop is provided with a series of "stops," which, as the cylinder is lowered—by appropriate means hereafter to be illustrated—enter the spaces between the guides, stopping all communication between the guides of the platform and the buckets of the wheel.

1943. *Fourneyron's Turbine.*—In Plate XXX. we give in fig. 1 a vertical section, and in fig. 2 a plan, of a Fourneyron turbine of three-horse power, manufactured by Messrs Williamson, of Canal Ironworks, Kendal. It has been erected at the farm of William Wilson, Esq. of High Park, near Kendal. It is employed to drive the machinery of the barn, as the thrashing-machine, a pair of stones for grinding meal, straw-cutters, root-slicers, &c. The following is a description of the figures in the plate: *a* is the pipe by which the water is conveyed into the wheel-case or cistern *b b*, in the lower part of which are cast the guide-curves *c c*, shown partially on the ground-plan, fig. 2, at *c c*. The water passes between these guide-curves, and is directed by them so as to strike against the buckets of the wheel *d d*. The wheel is formed chiefly of cast-iron, the buckets or vanes being of galvanised wrought-iron. The curve of these vanes should be so formed that the water may press steadily against them during its passage through the wheel, afterwards escaping from them without velocity. Between the guide-curves and the wheel is a circular sluice *e e*, fig. 1, which can be raised or depressed by means of brass screws *f*. These screws have at the upper end pinions *g*, all working into a centre wheel *h h*, which works loose on a projecting part of the case. One of the pinion-spindles is lengthened, and has on it a hand-wheel, which, when turned, acts through the wheel simultaneously on the three screws, and raises or depresses the sluice-ring *e e*. This gearing is shown in dotted circles on the plan, fig. 2. The foundation-plate is at *i i*, from which the wheel-cistern is carried by three wrought-iron columns *k k*. The wheel is keyed on a wrought-iron shaft *l*, the lower part of which is bushed with brass to receive the pivot *m*. This pivot is of steel, and admits of adjustment by brass nuts. A groove *n n* is formed in the bush, and a suitable opening provided, to keep the pivot constantly cool and clean by a flow of water over its surface.

1944. *Thompson's Vortex-Wheel.*—In some modifications of the turbine recently introduced, the water is received at its circumference and discharged at its centre. Of this class the form known as the "vortex wheel," patented by Mr James Thompson, A.M., of Belfast, has obtained a high reputation. In fig. 3, Plate XXX., we give a section, and in fig. 4 a plan, of a five-horse power vortex-wheel, manufactured also by Messrs Williamson of Kendal. This machine has been erected at Holmscales Farm, near Kendal, the property of W. E. Maude, Esq., of Liverpool. It is nominally of five-horse power, and is worked with a fall of 30 feet, the water being confined within a 9-inch pipe; the diameter of the wheel is only 10 inches, and 2¼ inches in depth. It is employed to drive a very complete set of barn machinery, as thrashing-machine, as also straw-cutter, cake-crusher, turnip-pulper, and a circular saw. *a a* is a portion of the pipe by which the water is brought down into the wheel-case *b b*, which is simply an annular cast-iron box, closed externally, but having at its internal circumference four guide-blades *c c c*, between which the water passes, and by which it is directed in such a manner as to strike the buckets of the wheel. In the example before us, these passages between the guide-blades are made of the exact size required for the passage of the quantity of water which it is intended that the wheel shall consume when at full work, but under circumstances where the supply of water is irregular, and where economy in the consumption, in seasons when the supply is deficient, is of more importance than some additional first cost in the machine, the blades are made in such a manner that the opening can be enlarged or diminished at pleasure to correspond with the supply of water. *d* is the upright shaft by which motion is transmitted to the machinery, and on which the wheel *e e* is keyed. This wheel is composed of a thin plate of wrought-iron, on each side of which is built a circle of buckets, shown in dotted lines on the plan fig. 4. These buckets are closed on each end, but are open at their inner and outer circumferences, and the water entering at the exterior is discharged at the interior, and escapes through corresponding openings in the wheel-case. *f*, fig. 3, is the pivot of lignum vitæ on which the upright shaft *d* is supported; it is fixed in a cast-iron bridge, and so constructed that it may be raised and depressed by a brass set bolt *g*. This pivot is kept constantly immersed in water, and grooved in such a manner as to maintain a regular flow over its surface, in order to keep it perfectly cool and clean.

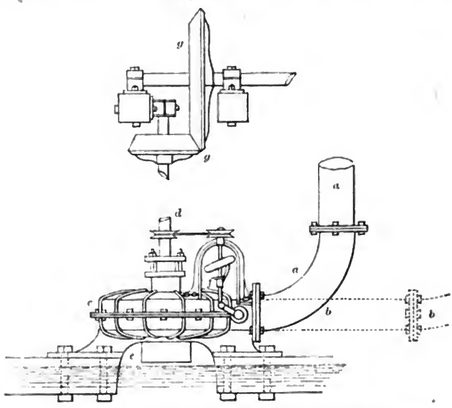
1945. In figs. 5 and 6, Plate XXX., we give a vertical section and plan showing the arrangement of the pit in which the turbine is fitted up. The well or pit *a a*, fig. 5, is sunk close to the wall of the barn; *b* is the drain by which the pipes containing the water are brought to the wheel, and *c c* of fig. 6 is the discharge-conduit or tail-race. *d d* are the pipes, 9 inches diameter, for conveying the water into the wheel-case *e*, and are supported in the well by two brackets *f f*, bolted to strong beams built in the walls. By this means easy access can be obtained to the pivot below the case, and the case itself can be readily removed without disturbing the pipes. *g g* is the upright shaft, on the lower part of which is keyed the vortex-wheel, and which is steadied by pedestals on brackets fixed to the pipe *d d* and to the wall of the barn. At the upper end of *g* are the bevel-wheels *h h*, by which motion is given to the horizontal shaft *i i*. This shaft traverses the barn, and on it are a range of drums, for giving motion to the various machines.

1946. The price of a six-horse power vortex-wheel, 10 inches diameter, 2½ inches thick, adapted for a fall of 44 feet, and consuming 95 cubic feet of water per minute, is £40.

1947. *Gwynne's Turbine.*—In fig. 777 we give an elevation, and in fig. 778 a vertical section of a turbine, invented and manufactured by Messrs Gwynne and Co., of Essex Wharf, Strand, London.

1948. Fig. 777 is an end elevation of the improved turbine or horizontal water-wheel. The construction is somewhat similar to that of the centrifugal pump, described in par. 1895, but the action is the opposite. *a a* is the feed or supply pipe, which brings the water from the fall or other source of supply: it may be placed in any other position, as shown by the dotted lines *b b*; *c* is the case or receiver of the wheel, fixed on a solid stone foundation; the wheel works inside the case *c*, and is keyed upon the vertical shaft *d*; the arms of the wheel are formed somewhat similar to those in the centrifugal pump, but as they approach the centre they sweep gradually round like a screw, and terminate downwards into the pipe *e* at right angles to the commencement of the arms. When the water

Fig. 777.



END ELEVATION OF GWYNNE'S TURBINE—SCALE, ¼ INCH TO THE FOOT.

enters through the pipe *a a*, it acts upon the arms while passing through the case to the only exit *e*, where it escapes; and the screw-like termination of the arms, seen at *g*, fig. 778, absorbs from the escape of water any velocity it may retain exceeding that at which the wheel is moving; so that in this way the maximum power is obtained from the direct pressure of the water; it also acts upon the wheel by its reactive motion. An improved governor is shown at *f*, fig. 777, by which the speed of the wheel is regulated. The power of the wheel may be conveyed as desired by the bevel-wheels *g g*, and the upright shaft *d* may be of any desired length.

Fig. 778.

VERTICAL SECTION OF GWYNNE'S TURBINE—SCALE, ¼ INCH TO THE FOOT.

1949. Fig. 778 is a section of the turbine, where *a a* is the bed-plate by which it is bolted to the foundation; *b* the wheel-case, obtaining its supply of water from the pipe *c c*; *d d* the wheel; *e* the vertical shaft supported in bearings *f* and *g*.

1950. The price of Gwynne's turbine may be set down at £40. The power will depend upon the fall.

1951. SECTION THIRD.—*Steam Power.*

1952. *The Steam Engine.*—We deem it scarcely necessary to enter into a detail of the important uses to which the steam-engine can be put, in the general business of the farm; yet, considering the numerous employments in other pursuits in which it is a powerful aid, it is somewhat surprising that its adaptation to agriculture has been so amazingly tardy. In the varied branches of our manufactures the steam-engine plays an important part. With its aid we produce the plainly useful as well as the beautifully elegant of our textile fabrics. Aiding untiringly in simple operations, as the turning of the potter's or the knife-grinder's wheel, it directs, with equal ease and unvarying precision, the complicated motions of our rarest and most cunningly-devised mechanism. But not only have we to admire the power of the steam-engine; the ease with which it can be controlled claims also our consideration. While treating of its force, we must not forget its gentleness; performing labour with untiring energy, which the might of a hundred men would be useless to effect, this power is controlled by the aid of an infant's hand. With a power so great and so untiring, yet so easily controllable, and with a facility of adaptation to almost any kind of labour which the energy of man or the muscles of our horses have been accustomed to perform, the steam-engine is apparently destined to aid the farmer, as it has so ably aided the manufacturer; and it is gratifying to notice the increased and increasing attention which our agriculturists are giving to this important aid to progress. Scarcely can we enter into the discussion of an agricultural society, or peruse the records of an agricultural journal, but what in some way or other the steam-engine is mentioned, either in the way of recommendation of its economy, or in corroboration of its powers.

1953. *Properties of Steam.*—In giving our remarks on this important department of agricultural mechanism, the subject we shall first consider is the "Properties of Steam." Steam, theoretically, is the vapour produced from water at any degree of temperature. For practical purposes, however, steam is defined as the vapour of water when heated by artificial means to the boiling-point, or 212° Fahr., and upwards. It is distinguished from other gaseous or aëriform fluids by its property of convertibility into the form of water, from which it is produced, other gases having the property of permanent retention of their aëriform condition. From this property of steam is derived one of the sources of its mechanical power. The elasticity of steam is that property by which it expands its bulk or volume, and tends to free itself from the space in which it may be confined. In the steam-engine boiler the amount of elastic force is estimated by the pressure against the safety-valve, or by the maintenance of a column of water in the feed-apparatus, or of mercury in the steam-gauge. Generally the elasticity is measured by or compared with that of the ordinary atmosphere, the density of this being represented by a barometrical column of mercury 30 inches high. The elasticity of steam depends upon its temperature, the elastic force being increased in proportion to the rise of temperature. The following table shows the rate of increase, or the connection between the temperature and elastic force of steam. Thus at 212° of temperature the elastic force of steam is estimated at one atmosphere, or 15 lb. to the square inch; at 250° of temperature, it is estimated at two atmospheres, or 30 lb. to the square inch, and so on as follows, discarding fractions, and extending to ten atmospheres, or 150 lb. to the square inch:—

Temperature.	Elastic Force.	Temperature.	Elastic Force.
275°	3 atmospheres.	294	4 atmospheres.
307	5 „	320	6 „
332	7 „	342	8 „
351	9 „	359	10 „

1954. Water, on being converted into steam, increases in bulk or volume to a large extent: a cubic inch of water forming a cubic foot of steam; or, in other words, it expands into 1728 times its former bulk; this is on the supposition that the pressure is at 15 lb. to the square inch. In common with other gases, the degree of expansion is in proportion to the pressure; with double pressure the degree of expansion is nearly one-half. The expansibility or expansive force of steam is another source of mechanical power, and may be defined as the power possessed by the particles of steam of receding from one another, so as to occupy greater space with the same weight. As above stated, the bulk or volume of the steam produced from a given quantity of water varies in proportion to the pressure under which the steam is raised. At 20 lb. on the square inch, the bulk is not 1728 times that of the water, as is the case when the pressure is 15 lb. to the square inch, but is decreased to 1280 times. At 25 lb. to the square inch, the bulk is 1044; at 35 lb., 767 times; at 40 lb., 678; at 45 lb., 610; and at 50 lb., 554 times.

1955. Another remarkable feature of steam is its latent or concealed heat: by this term is meant the amount of heat consumed in producing the evaporation, over and above that which is necessary for the raising of the temperature; and it is termed latent in consequence of its not being evident to the thermometer. From practical experiment, the latent heat of steam has been estimated to amount to 1000°. Supposing a quantity of water is raised from the temperature of 32° to 212°, or the boiling point, in a certain time,—to raise this quantity of boiling water into steam the time consumed will be 5½ times that formerly required, the amount of heat given out by the fuel used being all the time invariable in intensity. From this it may be seen that it takes 5½ times the amount of heat to raise a given quantity of water into steam that is required to raise the same quantity of water from the freezing-point, 32°, to the boiling-point, 212°; or, as generally expressed, to raise 1 lb. of water into steam from the temperature of boiling water, takes as much heat as will raise 5½ lb. of water from the freezing to the boiling point. Hence is deduced the amount of the latent heat of steam: the boiling-point, 212°, is 180° above the freezing, 32°; 180 multiplied by 5½ gives 990, or 1000, as it is generally stated. It is from a knowledge of this fact of latent heat that the large quantity of fuel expended in raising steam in steam-engine boilers is easily accounted for. The amount of latent heat of steam now mentioned is that where it is generated under the ordinary pressure of 15 lb. to the square inch; at higher temperatures or pressures the amount of latent heat is decreased, and this in proportion to the increase of pressure. At all pressures, the total amount of latent heat, and that indicated by the thermometer, is invariably a constant sum—namely, 1212°. Thus, where the pressure is increased so as to raise the temperature to any certain amount, the latent heat of the steam will be equal to the amount left after subtracting the temperature of the steam from 1212°: thus, if the temperature of the steam is 400°, the latent heat of the steam is 812°; if the temperature is 300°, the latent heat is 912°, and so on. From this is deduced the important truth, that by no alteration of pressure will a greater economy of fuel be obtained: but that, on the contrary, the consumption of fuel in raising a given quantity of water into steam is the same, whatever be the amount of pressure.

1956. *High and Low Pressure Steam.*—Steam, as used for mechanical purposes, may be divided into two classes—"high pressure" and "low pressure." By the latter is meant steam raised under a pressure a little above that of the atmospheric pressure, and which varies from 19 to 25 and 30 lb. to the square inch. When loaded to 20 lb. on the square inch, the steam passed into the cylinder is calculated, in good engines on the low-pressure system, to give 17 lb. on the square inch of the piston. Steam of 25 lb. on the boiler-valve, with 20 lb. on the piston, will be efficient in low-pressure engines. High-pressure steam is that raised under a pressure of from 30 lb. to 90 lb. on the square inch. Steam raised at the temperature of 212° is called steam of one atmosphere, and its pressure is 15 lb.; steam of 30 lb. pressure is called steam of two atmospheres; of 45 lb. of pressure, steam of three atmospheres. The pressure at first fixed by the Royal Agricultural Society was 45 lb. to the square inch; it is now 50 lb. In view of the important results derivable from the system of working at high pressure, there is little doubt but that this limit must be soon exceeded. Mr Waller is of opinion that it might be raised to 70 lb. or 75 lb. with advantage. Mr Bethell proposes to work at a pressure of 200 lb. to the square inch; while Mr Collinson Hall, in his compact portable engine exhibited at the Salisbury Show in 1857, works at the enormous pressure of from 300 lb. to 320 lb. on the square inch, working at this with safety, and with an expenditure of fuel unprecedentedly low. All experience shows that we are about to enter on a wide field of "steam-engine working" by the employment of high pressure, far above what is now considered by many safe or advisable.

1957. Although condensing engines are called low-pressure engines, it does not follow that they are worked with low-pressure steam: now that the expansive principle of working is so much carried out, condensing engine-boilers are often loaded with 40, 50, 60 lb., and, in some instances, as high as 70 lb. to the inch.

1958. Where evaporation of water is carried on quickly, the violent ebullition causes the steam to take up with it a quantity of watery particles; this is a fruitful source of mischief in the working of engines, as will hereafter be noticed. Where means are taken to allow the water to detach itself from the steam before the latter is passed to the engine, the steam is termed dry or anhydrous. An arrangement will be figured hereafter by which this important end can be carried out.

1959. It is important to note that impurities in water not only, in some instances, cause great deterioration in the boiler, but also retard very considerably the formation of steam. Mr Templeton, in his useful work entitled the *Workshop Companion*, gives a "Table," from which we draw up the following statement: The boiling-point of pure water being taken at 212°, sea-water containing salts, the proportionate quantity of the solid parts of which in 100 parts by weight of water is 3.03, does not boil at 212°, but at 213°.2. Where common water has an impurity of *sulphate of soda* equal to 31.5 parts in every 100 parts by weight of water, the boiling-point is 213°. When there are 64 parts of *sulphate of iron*, the boiling-point is 216°. When the water has 52 parts of *alum*, the boiling-point is 220°; with 45 of *sulphate of lime*, the same; with 57½ of *sulphate of magnesia*, 222°; with 30 of *muriate of soda*, 224°; with 60 of *nitrate of soda*, 246°; and with 60 of *acetate of soda*, 256°. And the degree to which the impurity of water may impair the elasticity of steam may be gathered from the following—that, with common water, the boiling-point of which is at 212°, the elastic force of steam, in inches of mercury, is measured at 30 inches; that of *sea* water, under the same circumstances, is only 23.05 inches. Common water at 220° shows an elastic force of 35.1 inches; sea water at 200° only 26.5 inches.

1960. *Effect of the Condensation of Steam.*—In the condensing or low-pressure engine the mechanical effect is produced by the condensation of the steam, and by its expansive action. The rationale of the mechanical effect produced by condensation is very simple. As before stated, par. 1953, steam differs from other gases in being capable of being retained in the aëriform state only by a retention of its temperature; by lowering this, either gradually or instantaneously, the vapour is reduced to its original form of water—a cubic foot of steam taking the form of a cubic inch of water. Let us suppose a cylinder provided with a tight-fitting piston, and having a capacity, when the piston was raised to its full height, of 1 cubic foot—suppose this filled with steam at the ordinary atmospheric pressure,—on being condensed, the steam will be reduced to the space of 1 cubic inch of water, which will occupy the lower portion of the cylinder, all the remaining portion between the surface of the water and the under side of the piston being a vacuum more or less perfect. The upper side of the piston, being open to the external atmosphere, is pressed down into the cylinder with a force of 15 lb. to the square inch, and, if supplied with proper appliances, would pull up a certain amount of weight hung by a chain over a pulley, the weight so raised being a measure of the mechanical effect produced. Here it is evident that the real amount of mechanical effect produced by the condensation of 1 cubic foot of steam into 1 cubic inch of water, will be precisely the same as the effect produced by the raising of a cubic inch of water into a cubic foot of steam.

1961. What this mechanical effect is will be seen from the following. As before stated, par. 1954, a cubic inch of water expands into steam sufficient to fill the space of a cubic foot, or 1728 cubic inches. Now, supposing a cylinder to be provided with a piston loaded with a weight of 15 lb. to its area of 1 square inch, and a cubic inch of water placed beneath it—by raising the water into steam the piston would be raised 1728 inches high, supposing the cylinder to be long enough; here the mechanical effect produced has been the raising of 15 lb. 144 feet high, or 2160 lb. raised 1 foot high. Hence the calculation which has been made is, that, by the evaporation of 1 cubic inch of water, the mechanical force produced is nearly equivalent to the raising of 1 ton 1 foot high (2240 lb. $=$ 1 ton $-$ 2160 lb. $=$ 80 lb.) This theoretical effect is the same in all cases, whatever be the pressure under which the steam is raised: thus steam raised at 45 lb. to the square inch will only raise the piston one-third the height, or 48 feet; but 48×45 (the pressure) is equal to the same as 15×144, or 2160. Of course, in practice large deductions are to be made, for friction and other causes, from this the theoretical effect produced by the evaporation of a cubic inch of water into steam.

1962. *Effect of the Expansion of Steam.*—The expansive properties of steam afford another source of mechanical power in the condensing steam-engine. We shall here point out this property only generally, giving it further investigation when we have explained the mechanism of the condensing engine. The pressure of air or of gaseous fluids varies according to the spaces into which they are compressed: thus, a quantity of air forced into a vessel so as to occupy only half the previous bulk, its elastic pressure is increased to twice the amount; if compressed so as to go into one-fourth the space, the elastic pressure is increased four times. On the other hand, if a gas is allowed to expand into a space twice its original bulk, the pressure is decreased one-half; if allowed to expand four times its original space, the pressure is diminished to one-fourth of its original pressure. Steam, in common with other gases, obeys the same laws. Suppose steam of a certain pressure is admitted to press upon the piston of a steam-engine, and that at the middle of its stroke—or when half of the space of the cylinder remains to be passed through—the entrance of the steam to the cylinder is cut off,—by virtue of the expansive properties of steam, the piston is propelled to the extremity of the cylinder through a space equal to half its length: the space into which the steam is passed is, however, twice its original bulk, and, in virtue of the law of expansion of gases just pointed out, the pressure is reduced one-half. Supposing the force of the pressure of the steam to have been originally half a ton, on finishing its stroke the pressure on the piston would only be a quarter of a ton. By this method of working it is evident that half a cylinder of steam is saved, and that although the power by which the piston is impelled is gradually decreasing as it approaches the completion of the stroke, it is clear that this power, whatever be its aggregate amount, is gained without any expenditure of steam, and consequently fuel. "The power of the engine," says an authority on this point, "is of course diminished by this procedure; for the piston will descend with less force when urged merely by the diminishing effort of the expanding steam, than if pressed upon by steam of the full pressure, entering to the end of the stroke from the boiler. But steam, or in other words fuel, is saved in a greater proportion than the power of the engine is diminished; so that the expansive principle augments, and very materially too, the motive efficacy of the fuel." While explaining the methods adopted of working steam expansively, we shall enter further into the investigation of this important principle.

1963. *Efficiency of Fuel.*—Steam, for practical purposes, is raised by the combustion of fuel of various kinds and qualities; an investigation into the methods to be adopted for getting the greatest efficiency out of the least quantity of fuel is therefore of the greatest importance. This inquiry necessitates an investigation into the various appliances connected with furnaces and boilers. The mechanical effect produced by the combustion of a given quantity of fuel is generally stated somewhat as follows: In ordinary land-boilers the combustion of 1 lb. of coal will raise from 6 to 8 lb. of water into steam; in some Cornish boilers the quantity raised by the combustion of 1 lb. is much higher—as high as 9 and 10 lb. A horse-power is calculated to be equivalent to raising 33,000 lb. 1 foot high per minute, and is attained by the evaporation of 1 cubic foot of water into steam per hour—6 lb. of coal being required to raise this quantity of steam. By the consumption, then, of 6 lb. of coal per hour, a mechanical effect of 1-horse power may be obtained. A much greater degree of economy is, however, attained in large engines working expansively. In some of the Cornish mining engines, 1-horse power is attained by the combustion of little more than 3 lb. of coal per hour; and in some to such an extent has economical working been carried, that, by the combustion of about 1¾ lb. of coal per hour, a mechanical effect equivalent to 1-horse power has been obtained; showing the enormous duty of 100,000,000 of lb. raised 1 foot high per minute by the consumption of 94 lb. of coal. It is gratifying to be able to state that the engines manufactured by agricultural-implement-makers show results which rival those of the celebrated Cornish engines just referred to. The trials of many of them showed that so small a consumption of fuel as 3½, 4, and 4½ lb. per horse-power per hour was attained, while, under circumstances of ordinary working, 5½ and 6 lb. were sufficient to give out a horse-power. Mr Hall states that in his engine, previously alluded to (par. 1956), the consumption is only 1¼ lb. of coal per indicated horse-power per hour. Amazingly economical of fuel as this plan of working appears to be, an able authority states that he believes it is able to be carried out with high pressure and sufficient expansion.

1964. The evaporative effects of various fuels differ in different qualities. Thus Newcastle caking-coal takes 8½ lb. nearly to raise a cubic foot of water into steam; Staffordshire takes more than 11 lb. Government recently instituted an inquiry into the evaporative effects of fuel and their management. From the Report* issued, which contains a vast amount of practical information,

* *Report of Experimental Investigations on Coals for the Steam Navy.* By Sir H. DE LA BECHE and Dr LYON PLAYFAIR.

we derive the following useful table, showing the economic values of various coals experimented on :—

Names of Coals used in the Experiment.	Economic evaporating power, or number of pounds of water evaporated from 212° by 1 lb. of coal.	Weight of 1 cubic foot of the coals, as used for fuel.	Weight of 1 cubic foot, as calculated from density.	Weight of water evaporated from 212° by 1 cubic foot of coal.	Rate of evaporation, or number of pounds of water evaporated per hour.
Welsh Coals.		lb.	lb.		Mean.
Graigola, ...	9.35	60.166	80.107	581.20	441.48
Anthracite, Jones & Co.,	9.46	58.25	85.786	565.02	409.37
Old Castle Fiery Vein, .	8.94	50.916	80.42	455.18	464.30
Ward's Fiery Vein, .	9.40	57.433	83.85	608.78	529.90
Binea, ...	9.94	57.08	81.357	587.92	486.95
Llangennech, . .	8.86	56.93	81,85	523.75	373.22
Pentrepoth, . . .	8.72	57.72	81.73	518.32	381.50
Pentrefelin, . . .	6.36	66.166	84.726	489.62	247.24
Duffryn, ...	10.14	53.22	82.72	540.12	409.32
Mynydd Newydd, .	9.52	56.33	81.73	536.26	470.69
Three Quarter Rock Vein,	8.84	56.388	83.60	498.46	486.86
Cwm Frood do., . .	8.70	55.277	78.299	480.90	379.80
Cwm Nanty Gros, . .	8.42	56.0	79.859	471.52	404.18
Resolven, ...	9.53	58.66	82.354	559.02	390.25
Pontypool, ...	7.47	55.7	82.35	416.07	250.40
Bedwas, ...	9.79	50.5	82.6	494.39	476.96
Ebbw Vale, . . .	10.21	53.3	78.81	544.19	460.22
Porth Mawr, . .	7.53	53.3	86.722	401.34	347.44
Coleshill, ...	8.0	53.0	80.483	424.0	406.41
Scotch Coals.					
Dalkeith Jewel Seam, .	7.08	49.8	79.672	352.58	355.18
... Coronation do.,	7.71	51.66	78.611	398.29	370.08
Wallsend Elgin, . .	8.46	54.6	78.611	460.82	435.77
Fordel Splint, . .	7.56	55.0	78.611	415.80	464.98
Grangemouth, . .	7.40	54.25	80.48	401.45	380.40
English Coals.					
Broomhill, ...	7.3	52.5			
Lydney, Forest of Dean,	8.52	54.444			
Irish Coal.					
Slievasdagh anthracite, .	9.85	62.8	99.57	618.58	473.18
Patent Coals.					
Wyolam's, ...	8.92	65.08	68.629	580.51	418.89
Bell's, ...	.53	65.3	71.124	557.0	549.11
Warlick's, ...	10.36	69.05	72.248	715.35	457.84

1965. It is but right to state that the results here tabulated are considered by some authorities as by no means conveying a correct notion of the evaporative values of the various coals referred to.

1966. It might be advantageous were some of our agricultural societies to institute experiments relative to the evaporative powers and the best method of management of various qualities of coal used in our agricultural districts. With the prospect of a large increase of steam power among our farms, this investigation would be highly valuable. None but those who have had practical experience in the management of steam-engines can have an accurate idea of the importance of good fuel, and of good methods of management. It must be very evident, even to the most superficial observer, that on the economical operation of the furnace depends in great measure the economical working of the steam-engine.

1967. We conclude this department of our subject, by giving the following table, for which we are indebted to the valuable work of Tredgold (Walton & Maberley, London) on Warming and Ventilating; it will be useful as affording a ready means of judging of the comparative evaporative powers and cost of various fuels.

Kind of Fuel.	Quantity in lb. that will heat one cubic foot of water one degree.	Quantity in lb. that will convert one cubic foot of water into steam.
Newcastle caking-coal,	0.0075	8.4
Splint coal (nearly the same),	...	...
Staffordshire coal (cherry coal),	0.0100	11.2
Culm,	0.0196	22.0
Wood (dry pine),	0.0172	19.25
Wood (dry beech),	0.0242	27.0
Wood (dry oak),	0.0265	30.0
Peat (of good quality),	0.0475	53.6
Charcoal,	0.0095	10.6
Coke,	0.0069	7.7
Charred peat,	0.0205	23.0

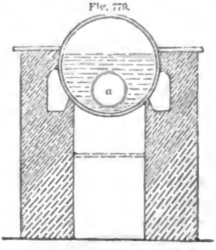
1968. By the above, the superiority of coke over coal is shown: thus, taking 8.4 lb. of Newcastle coal to raise a cubic foot of steam, 7.7 lb. only of coke is required.

1969. *Varieties of Boilers.*—We now come to describe and illustrate the two varieties of boilers principally used for agricultural purposes; namely, the cylindrical and the flued or tubular boiler.

1970. *Cylindrical Boiler.*—The form of cylindrical boiler most generally used for small high-pressure engines is shown in Plate XXXI. It is in shape a true cylinder, with hemispherical ends. When hung with a "direct draft," or on "the oven plan," as it is termed, the flame and smoke pass at once from the furnace *b*, fig. 2, across the bridge *c*, along the bottom *d*, and to the chimney through the flue *e*. This method of setting cylindrical boilers is much to be deprecated, from the liability to explosion from the flame and heated air getting access to the boiler above the water-line. This will be more fully entered into while treating on boiler explosions, their causes and remedies.

1971. Another way to set a cylindrical boiler is to have side-flues, as *e e*, fig. 1, Plate XXXI., so as to form a wheel-draught, the course being over the bridge *c*, and along the bottom of the boiler to the further end, where it rises at the back, and from the back to the front of the furnace, through one of the side-flues, round the front of the boiler, and, turning into the other side-flue, finally passes into the chimney.

Fig. 779.

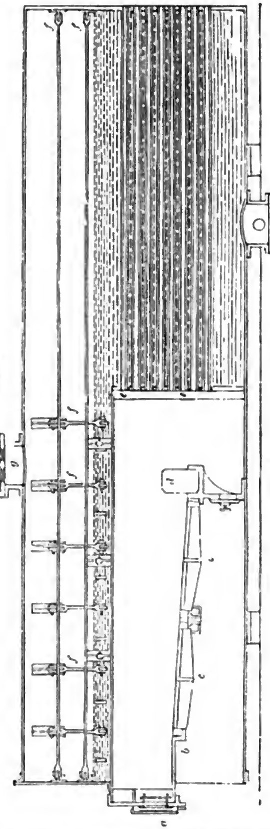


FLUED CYLINDRICAL BOILER.

1972. Cylindrical boilers for high-pressure engines are sometimes made with an internal flue, as *a*, fig. 779. With this form of boiler the draft is what is termed a "split draft," the flame and heated smoke passing from the furnace along the bottom of boiler, to the end of the furnace, and, rising up to the internal flue *a*, passes to the front of the boiler, where it divides and traverses the two side-flues, and from thence into the main chimney-flue.

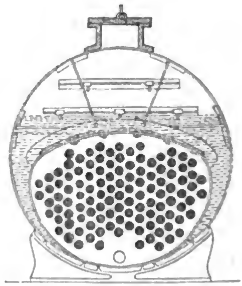
1973. *Multitubular Boiler.*—A form of boiler rapidly extending in use, and based upon that of the locomotive, is known as the multitubular or fire-box boiler. This form of boiler is one generally adapted to the portable engines of the farm, but is equally applicable, under slight modifications, to stationary engines. In fig. 780 we give a longitudinal section of the multitubular boiler, now being largely introduced by Messrs Gordon and Co., engineers, of Stockport. With this boiler, steam can be raised in a very short space of time. *a* is the furnace-door, *b* the dead-plate, *c c* the furnace-bars, *d* bridge, with valve for admitting air to consume the smoke beneath it, *e e* tubes passing through the boiler, *f f* stays to strengthen the boiler, *g* the man-hole door. In fig. 781 we give a transverse section of boiler, showing position of tubes and stays; and in fig. 782 end elevation, showing fire-doors *a a*, *b* ash-pit, *c c* end of boiler, *d* man-hole door, *e e* standards on which the boiler is supported. In Plate XXXII. we give views of a boiler on this principle.

Fig. 780.



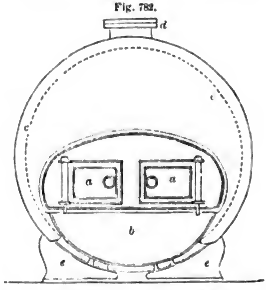
MULTITUBULAR OR FIRE-BOX BOILER.

Fig. 781.



TRANSVERSE SECTION OF MULTITUBULAR BOILER.

Fig. 782.



END ELEVATION OF MULTITUBULAR BOILER.

1974. *Details of the Cylindrical Boiler.*—We proceed to describe in detail the various parts of these two classes of boilers, and, first, of the cylindrical, illustrated in Plate XXXI. This is generally constructed of the best Staffordshire plate, the plates being generally bent to the circle while in a cold state by the aid of rollers. The joinings are all effected by riveting with short bolts ⅝ths of an inch in diameter, the rivet-holes being previously made by the aid of a punching-machine. The rivets are inserted and closed up in the hot state, so that, besides the effect of riveting to draw the contiguous surfaces of the plates into close contact, there is the powerful contraction of the iron while cooling to produce still more perfect contact. To insure perfect tightness in the joinings or *landings*, technically so called, the whole of the joints, after they are riveted up, undergo a process of caulking, which is simply stamping up the edges of the adjoining plates into intimate contact by means of flat-edged chisels struck with a hammer.

1975. The figs. 1, 2, and 3, Plate XXXI., represent a plan and two sections of a *steam-boiler* for a 6-horse engine. Fig. 3 is the *plan*, the one-half of it taken above the level of the boiler's bottom, the other half below that level. *a* is the furnace-door and dead-plate, *b b* the furnace-bars, and *c* the bridge or throat of the furnace, over which the flame is drawn with great force, proceeding along the flat flue *d* to the extremity *e*, where it is turned into the first side-flue *f*. The figure exhibits also the top of the boiler *g*, but without any of its furniture; *h h* is the continuation of the flue round the end of the boiler, leading into the other side-flue *i i*, which terminates in the chimney *k*; *l l* are walls of the boiler-seat, and *m m* the flue-ports, which are movable plates, to admit of access to the flues for the purpose of cleaning. The damper *i'* is a metal plate suspended by a chain, and its purpose is the increase or diminution of the draught.

1976. Fig. 2 is a longitudinal section, in which *a* again marks the furnace-door, *b* the furnace-bars, *c* the throat, and *d* the flat flue, *e* being the first bend of the flue, and *h* that part of it that turns the front of the boiler. The boiler *g g* appears here in complete section, *r* being the feed-pipe from the engine-pump, delivering the water near the bottom of the boiler; *o* is the man-hole door, and *p* the steam-pipe, for conveying the steam to the engine; *q* is the safety-valve, which should not be less than 3 inches diameter; and *n* is one of the gauge-cocks. The parts *l l* represent the brickwork of the boiler-seat; *m* is the ash-pit, and *n'* a closed port for the removal of dust from the dust-hole *d'*.

1977. Fig. 1 is the cross section, wherein *a* is the ash-pit, 3 feet in height; *b* the furnace-bars, *c* the bridge, and *d* the throat, which should not exceed 8 inches in height; *e e* are the side-flues—their breadth at bottom, measuring from the sides of the furnace, should be not less than 16 inches. The boiler is here represented by *g*, and the waste steam-pipe by *p*, *o* being the clasps of the man-hole cover, *q* the safety-valve, and *n* the feed-pipe; *k* is the chimney flue, and *m* is an entrance-port.

1978. *Details of the Multitubular Boiler.*—In Plate XXXII. we give figures, of a multitubular and flued boiler, of six-horse power, manufactured by Messrs Carret, Marshall, & Co., Leeds. Fig. 1 is a part transverse section, fig. 2 an end elevation, and fig. 3 a longitudinal section. *a a* the central flue, *b* the fire-bars, *c* ash-pit; *d d*, fig. 1, the tubes through which the heated air passes to the chimney *p*, figs. 2 and 3, in *front* of the boiler; *e e* are standards on which the boiler is supported, free from all brickwork setting; *f f*, fig. 1, glass water-gauge, *g g* steam-dome, *h* pillar for supporting water-indicator wheel and alarm apparatus. As the weight *i* rises and falls according as the level of water in boiler acts upon the float with which it is connected, it causes the float-rod to operate upon the lever *o*, and to open or shut the steam-whistle *n*. The apparatus thus acts as a water-indicator and a safety alarm. The furnace-door is at *r*; *s*, fig. 3, the spring safety-valve on top of dome, *t t* lever and spring-box, *v* cock of steam-pipe leading to engine, *x x* stays to strengthen the boiler, *w* furnace-bridge. This is an exceedingly compact and well-arranged portable boiler. On the principle of the "split draft," the heated air, after passing along the main flue, returns on either side through the smaller tubes *d d* to the chimney *p*, which is placed in front of the boiler. It has a favourable reputation as an economical and quick steam-raising boiler.

1979. As this boiler is perfectly independent of all brickwork—a feature which it possesses in common with the majority of other forms of multitubular boilers—it may be called a portable boiler, as it can be easily set down in different positions.

1980. *Vertical Tubular Boiler.*—A form of tubular boiler coming into use, and the principle of which is most favourably noticed by a first authority, is that known as the Vertical Tubular Boiler.

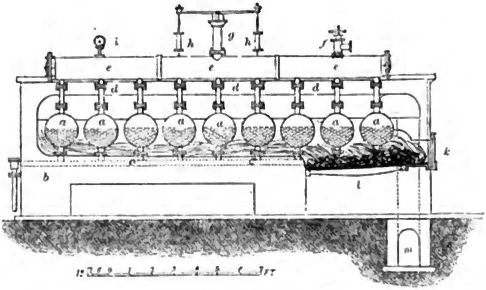
1981. Vertical tubes pass through the water-space; the heated air and smoke pass out at the upper end; an outer case of brick might be made to surround the boiler, and the smoke and heated air led downwards so as to circulate between the shell of the boiler and the casing, and finally passed to the chimney-flue. A practical authority recommends the fire to be covered with a brick dome, having on the crown perforations opposite the apertures of the tubes—thus obviating to a considerable extent the danger of the bottom tube-plate being burnt out.

1982. An objection to this plan of boiler is, that if the water supplied is of impure quality, a sedimentary deposit will accumulate on the bottom-plate; this inconvenience has, however, not been experienced in boilers in practice, and this, probably, from the extreme agitation of the water caused by the steam rushing upwards. To prevent deposit a blow-off cock should be attached to this boiler near the bottom, by which, from time to time, the water at the lower portion, with such sediment as may be therein, can be passed away from the boiler. The operation of "blowing out" can only be effected with certainty when the steam is at considerable pressure.

1983. In fig. 3, Plate XXXVII., we give a section of a vertical boiler manufactured by Mr William Walker, engineer, of Lower King Street, Manchester. In the figure, *a* is the fire-door; *b* the fire-bars; the heated air passes upwards through the tubes *c c c*, which are surrounded by water up to the level *d d*. The position of the water-level is indicated by the glass water-gauge *e e*, hereafter to be described; *f f* the steam supply-pipe; *g g* a blow-off pipe, connected with the main chimney-flue *h*.

1984. *Duplicate Retort Steam Boiler.*—We deem it right to notice here a form of boiler which, from the portability of its component parts, and the comparative immunity it gives from the dangers of explosion, we think applicable to stationary agricultural engines. It is known as the Duplicate Retort Steam-Boiler, the invention of, and manufactured by, Messrs Dunn, Huttersley, and Company, Windsor Bridge Ironworks, Pardleton, near Manchester. We give in fig. 783, a partly longitudinal section and side-elevation of a furnace and boiler on this plan. From this it will be seen that the peculiarity of the plan is the employment of a series of cylindrical retorts *a a a*, each of which constitutes a separate boiler. These retorts are placed in parallel lines, and the water supply-pipe *b* is connected with one end of each cylinder by short pipes, as *c c*. Through these water is pumped into all the cylinders, so as to maintain the supply up to their semi-diameter. As the steam from the cylinders rises, it passes off by pipes *d d d* to the interior of the steam-chest *e e e*, from which it is led off by a pipe attached to the stop-valve box *f*; *g* is the safety-valve pipe; *h h* the springs which regulate

Fig. 783.



DUPLICATE RETORT STEAM-BOILER.

the funnel; *i* the pressure indicator; *k* the furnace-door; *l* the fire-bars; *m* the smoke-flue leading to the chimney. The cylinders are made of the best ¼-inch Staffordshire iron, with cast-iron ends, and are tested, before fitting up, with a pressure of 250 lb. to the square inch, and guaranteed for two years. It will be perceived that the risk of explosion is comparatively little, as, in addition to the great strength of each retort, it will rarely happen that more than one retort will explode at the same time. The cylinders being small, a boiler of considerable power may be transported easily piecemeal. Again, the wear of the set may be equalised by shifting those which for a time have been subjected to the strongest heat, to a place where the heat is less intense. Another advantage possessed by this plan is, that each retort being independent of the others, it can be turned round, exposing gradually the whole of the surface, and thus wearing it out uniformly. Again, where muddy water is used, the sediment will collect in the retort furthest from the fire-grate, it entering this first. This first retort will also act as a water-heater of an extremely simple and efficient kind.

1985. *Proportions of Boilers.*—Having illustrated the varieties of boilers now in use, or attracting the attention of engineers as likely to be economical and quick raisers of steam, we finish this department of our subject by giving a few notes on the proportions of boilers with reference to their heating surfaces, the steam and water space, and the areas of fire-grate and chimney flues. The limits of our work preclude us from going as fully into this important point as we should have wished; but those desirous of thoroughly understanding the whole bearing of the case cannot do better than consult the pages of Weale's (High Holborn, London) shilling volume on "Steam-Boilers," by Mr Armstrong, one of our best authorities on the subject.

1986. The whole surface of the boiler exposed to the action of the heated air is by some engineers calculated as effective heating surface. This, however, is erroneous, and a fruitful source of disappointment as to working capabilities. It is now admitted by authorities that the surfaces on which the upward action of the heated air is brought to bear can only be effective heating surfaces. The under side, then, of flues is never calculated as heating surface. The upright or side surfaces of a boiler are calculated as being only half as effective as the surface on which the upward action of the heated air operates. The quantity of heating surface required for each horse-power—taking the evaporation of one cubic foot of water per hour as the measure of a horse-power—varies according to the rules or notions adopted by engineers, and to the peculiar circumstances under which the boiler is to be employed. Mr Armstrong, as the result of large personal experience, recommends an effective heating surface of 9 square feet, or one square yard, per horse-power—this applying to the generality of boilers now in use. The quantity of fire-bar or grate surface per horse-power is one square foot. This will be increased with advantage to $1\frac{1}{2}$ square foot. The proportion of furnace room is generally calculated at about 3 cubic feet per horse-power. The proportion of steam space in a boiler recommended by Mr Armstrong is "half a cubic yard for each nominal horse-power." Ten cubic feet of steam space per horse-power is the general proportion allowed; giving the same capacity for water space, this makes the water-line at half the depth of boiler. The total boiler-space, says Mr Armstrong, should be a cubic yard per horse-power, "not *more* than half of that space being water room, nor less than half of it for steam." This rule is borne out by the practice of the north of England engineers, who reckoned an efficient steam-engine to be that in which the area of piston in circular inches was 27 to the horse-power, and the capacity of the boiler 27 cubic feet per horse-power. In Lancashire the rule is—and this holds more especially for small engines, where economy of space is of more importance than economy of fuel—"for each square inch in the area of the piston to allow a cubic foot in the boiler."

1987. In increasing the evaporative efficiency of a boiler, a very common method adopted is to lengthen the boiler; the benefit thus obtained is derivable chiefly from the fact that the effective heating surface is increased. As a rule, however, a well-proportioned boiler is that in which the greatest amount of heating surface is compressed within the least possible length. Experience is in favour of the short boiler, the effective heating surface being as much as possible above the fire or grate surface, avoiding long narrow flues; a cylindrical boiler being, with a direct draft, as in fig. 2, Plate XXXI., about six diameters in length. Where a cylindrical boiler is set up with a "wheel draft," the proportion of length may be four diameters.

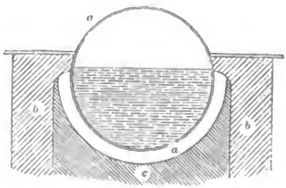
1988. *The Chimney.*—The chimney for the steam-engine is an object of some importance. Upon its height and area depend much of the future effects of the engine; and very numerous are the views taken of these by engineers. The following points may, however, be taken as data not easily controverted. The height should not be less than 50 feet; and if it is desirable to avoid the nuisance arising from smoke, the height should greatly exceed this. The internal sectional area should be as large as may be consistent with economy in the expense, but should never be under 80 square inches for each horse-power. Thus a chimney for a six-horse engine should have its area at the top $80 \times 6 = 480$ square inches, and $\sqrt{480} = 22$ inches nearly, the side of the square of the chimney internally; and if circular, the diameter should be 25 inches nearly. The height of the chimney being determined, and also the side of its square externally, the square of its base is found by adding to the length of the side at top the amount of increase arising from the slope given to the sides. The usual slope, or batter, is $\frac{3}{8}$-inch to a foot; with a height, therefore, of 50 feet, the increase at bottom will be $18\frac{3}{4}$ inches on each side; and the walls being one brick or 5 inches thick, the side of the square at top will be $22 + (5 \times 2) = 32$ inches, and this added to $18\frac{3}{4} \times 2 = 39\frac{1}{2} + 32 = 5$ feet $11\frac{1}{2}$ inches, the side of the square at bottom.

1989. Bolton and Watt's rule for finding the area of a chimney-flue for a land-engine is as follows: "Multiply the number of pounds of coal consumed under the boiler per hour by twelve, and divide the product by the square root of the chimney in feet; the quotient is the area of the chimney in square inches in the smallest part." A chimney 20 inches square inside, and 80 feet high, is considered a well-proportioned one for a 20-horse boiler, consuming 15 lb. of coal per horse-power per hour. 10 lb. of coal per hour is calculated to be the quantity that a square foot of grate will burn with advantage.

1990. *Check-Bridges.*—We shall now notice a few of the methods adopted and recommended for still farther rendering boilers economical. One method of increasing the evaporative efficiency of a cylindrical boiler set in the direct draught or oven plan is by building "check-bridges." The object of these appliances is not to retard the flow of heated air along the furnace, so as to retain it, and make it give out the most of its heat, but chiefly to cause it to envelope the lower part of the boiler.

1991. Fig. 784 shows the method of arranging these check-bridges—*a a* the boiler, *b b* the furnace, *c* the bridge. Care should be taken not to have the distance between the boiler and the upper edge of the bridge too great; in this case the heated air will have a tendency to pass through in an unbroken stream. The importance of breaking and agitating the gases in their passage along flues is now admitted by all our best authorities. Bolton and Watt, in their marine flued-boilers, have adopted an arrangement by which the gases are made to strike the sides of the (circular) flue.

Fig. 784.



CHECK-BRIDGES FOR BOILER FURNACES

1992. As showing the economical results to be derived from this plan of having check-bridges (fig. 784), we give the result of a series of experiments instituted by the well-known engineer, Mr Wicksteed, to ascertain the relative economy of a Cornish boiler set on the ordinary plan, and also with the new furnace having these check-bridges:—

	Without Check-Bridges.	With Check-Bridges.
Coals consumed per hour,	313 lb.	293 lb.
Water evaporated do.,	2.170	2.256
Do. per lb. of coals from instant temperature,	6.919	7.701
Do. from 212° (latent heat 1.000°),	7.725	8.640

1993. The last line shows that, when taking the coals from the heap, 1 lb. of coals, with this check-bridged furnace, evaporated 11.8 per cent more water than without the check-bridge. The experiments had reference more particularly to the testing of an American patent boiler, the peculiarity of which consisted entirely of a number of these check-bridges placed beneath a boiler hung on the direct-draft plan, the only claim to novelty being the *parabolic* form given to the front of the bridges. The method has been long in use in America, and is being adopted in this country. Mr Armstrong has long advocated its use. Mr Wicksteed states that he can have no hesitation in "declaring that the saving of 37 per cent upon the average, stated to have been effected in the American establishments, has been effected, and that there are numberless cases in Great Britain where a similar saving might be effected." A practical authority, who has instituted a great number of practical experiments on the evaporation of water and the consuming of smoke (Mr Green, manager of the large works of Messrs Hoyle, Dukinfield), states that those made with a boiler set in a furnace on this plan indicated better results than he had ever before obtained from any other furnace.

1994. In order to secure the perfect combustion of the gases, arrangements should be made to carry on the combustion of the fuel at the highest possible heat. To obtain this desideratum, it is a good plan to line the furnace with fire-bricks, even in the case of flued and tubular boilers. This should be done in the fire-box of the tubular boiler.

1995. Attention should be paid to the building of the fire-bridge at the end *c*, fig. 2, Plate XXXI., of the furnace. The office of this appliance is not merely to prevent the coals from being pushed too far by the stoker, but, as shown already, to cause the flame and heated air to envelope the boiler. The distance between the top of bridge and bottom of boiler should not be too great: a proportion will be one-sixth of diameter of boiler; that is, where the diameter of boiler is 4 feet, the distance between top of fire-bridge and bottom of boiler should be 8 inches. The top of the fire-bridge should not be flat, but concave, the radius of the circle being equal to that of the boiler (see fig. 784). The supply of air to the furnace is also of importance, the limit of distance between the fire-bars being that which will prevent the coals from dropping through. The flue leading from the boiler to the chimney will be sufficiently wide if it has a surface of 15 square inches to each horse-power; it is best, however, to make it wider than this, contracting it temporarily until the requisite draught is found, where it may be permanently fixed.

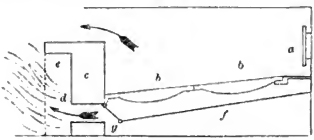
1996. *Quantity of Water in Boilers.*—It is generally understood that the keeping of a large quantity of water boiling involves no greater outlay of fuel than keeping a small quantity boiling. That this is erroneous Mr Armstrong very clearly shows: "A large quantity of water must require more heat, or heated surface, to keep it boiling, than a smaller quantity, even supposing the heat required to generate the steam to be equal in each case; for there must be a great deal of power expended in keeping the water in motion, and every practical mechanic knows that we never get power for nothing." Mr Armstrong recommends that the quantity of water should never exceed 17½ cubic feet per horse-power. And the same authority found that, by keeping the same relative amount of steam and water *space* as at first arranged for the boiler, but reducing the quantity of water by placing large stones on shelves amongst the water—thus leaving, as it were, mere sheets of water between the blocks and the sides of the boiler—considerable decrease in the consumption of fuel followed. The articles—as fire-bricks—should be laid down upon a platform of iron rolls, so as to be clear of the bottom and sides of the boiler; space being left, also, between each firebrick.

1997. *Economisation of Surplus Heat from Furnaces of Boilers.*—The fact that the heated air, even after passing from a boiler of considerable length, is still of such a high temperature as to be capable of boiling water, has led to the bringing out of numerous plans for using up the surplus heat. The flues and fire-bridges should be so arranged as to allow the heated air to be retained under the boiler as long as to pass it away when it has reached the temperature a little above that of the metal of the boiler.

1998. *Consumption or Prevention of Smoke.*—Economical working of furnaces is also to be obtained by efficient plans for preventing the formation of smoke. A few remarks may be acceptable on this important subject. As to the cause of large bodies of smoke being passed from our steam-engine furnaces, it seems to be generally acknowledged that "bad firing or stoking is one of the most fruitful and common." We have already pointed out the connection that should exist between the heating surface of the boiler and the area of the grate, and the quantity of fuel consumed therein, in order to obtain an efficient boiler (par. 1567). Now, it is quite evident that, if the grate is so proportioned as to consume efficiently a certain quantity of coal per hour, perfect or at least uniform combustion can only be maintained by uniformity of supply. If the quantity is laid in irregularly—that is, at irregular intervals—no degree of uniformity of combustion can be attained. An able authority thus puts the case in figures: Supposing the quantity of coals to be consumed per hour is 60 lb.; to preserve uniformity of combustion to as near an approach of perfection as practicable, the supply should be spread over the fire at the rate of 1 lb. of coal every minute: but in hand-firing the plan adopted is somewhat as follows,—placing 15 lb. of fuel in the furnace every 15 minutes. Now, on the supposition that the grate is properly proportioned, it is evident that, by this method of firing, the interval of 15 minutes between each firing will be divided thus: for one-half the time too little air will pass the bars; for the other half—as the coal is getting consumed—too much. Theoretically, the inconvenience might be overcome by stoking at shorter intervals; practically, however, this method involves as bad a state of affairs as it is apparently designed to remedy—by the frequent opening of the fire-door admitting a quantity of cold air to the furnace, which acts prejudicially. As regular firing—that is, firing with unvarying precision—is therefore so essential to the perfect combustion of the fuel, and as frequent meddling with the fire or too much stoking is also an evil to be deprecated, a plan by which the desideratum can be attained on the one hand, and the danger avoided on the other, is of great importance. To carry out this thoroughly, we must call in the aid of machinery. But as we consider "machine-firing" not essentially necessary in farming engines—as involving much additional expense, which could not be repaid from the comparatively little use which would be got out of it—we content ourselves by explaining how the arrangements can be adopted by which the evils of hand-firing can, in some measure, be obviated.

1999. First, as to furnace arrangements calculated to aid the object in view: for the perfect combustion of 1 lb. of coal 2 lb. of oxygen are required, and this is given in the 150 cubic feet of atmospheric air which must be passed through the burning fuel. A consideration of this necessity has induced numerous inventors to introduce plans by which air could be admitted to the furnace, or to operate upon the gases evolved from the partial combustion of the fuel. The best-known plan under this head is that named the "Argand Furnace," of which Mr Charles Wye Williams, Liverpool, is the inventor. In this plan, air is admitted at the back of the fireplace, through perforations in a row of pipes. The free admission of air meeting the dense smoke or gases, promotes the combustion of the hydro-carburets. But while tending to promote the combustion of the smoke, or rather to prevent its formation, the draught of the furnace is said to be liable to be checked; and it is further objected to the plan by some engineers that the admission of cool air below the boiler subjects this to a rapidly deteriorating influence through the irregular expansion and contraction. Mr Williams, in his treatise, *The Combustion of Coal and the Prevention of Smoke chemically and practically considered*, states that all that is to be done in order to enable employers of steam-engines to be independent of "smoke-consuming patents," is to imitate as near as possible the principle of the common argand gas-burner. Let them introduce the "air by numerous small orifices to the gas in the furnace, as the gas is introduced by small orifices to the air in the lamp. . . . . Let them begin by having as many half or even three-quarter inch orifices, with inch spaces drilled in the door and door-frame, as possible. If the furnace be large, and the door-plate frame is not sufficient for the introduction of the required number of holes, let them introduce the perforated plate in the bridge, as described by Dr Ure in his *Dictionary of Arts*, last edition, title 'Smoke Nuisance.'" The following is the figure alluded to, where *a*, fig. 785, is the furnace-door, *b b* the fire-bars, *c* the bridge, *d* the aperture leading the air to the chamber with perforated plate *e*. The regulating-valve *g*, worked by the rod *f* originally adopted, is not found necessary in practice.

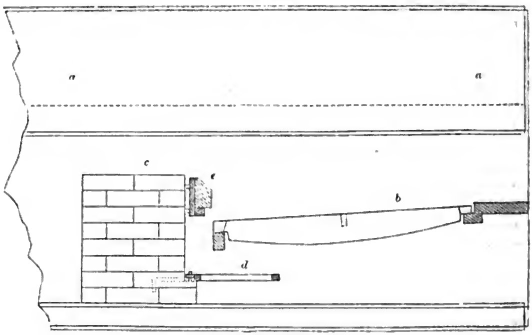
Fig. 785.



ARGAND OR SMOKE-PREVENTING FURNACE.

2000. To obviate the assumed or presumed defects of the admission of cold air, it has been proposed to heat the air before mixing it with the smoke. Of this class of inventions, the one most recently introduced, and which seems, from the numerous cases in which it has been tried, to prove efficient, is that known as the "Smokeless Furnace" of Mr Lee Stevens (King William Street, City, London). One great recommendation of this plan is its simplicity, the ease with which it can be fitted to any furnace, and the little danger there is of its getting out of repair. In fig. 786 *a a* is the boiler, *b* the fire-bars, *c* the bridge. The plan consists in the addition of a minor set of fire-bars *d*, placed under the

Fig. 786.

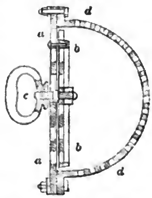


LEE STEVENS' SMOKELESS FURNACE.

ordinary fire-bars *b*, at the farthest end of the ash-pit. On this set of bars the scoriæ and cinders from the upper furnace fall. By this arrangement the current of air entering at the lower part of the furnace passes through two strata of fire, and thence between the "calorific plate" *e*, faced with fire-brick, and the bridge *c*. The air is thus so intensely heated as to produce the entire combustion of the gaseous products of the fuel without the formation of smoke. The supply of air seems to adjust itself in this arrangement very closely to the demand for it,—an important feature in any plan, obviating, as it does, any necessity for careful attention on the part of individuals who are not generally much inclined to give it. This plan, from its very simplicity, is worthy of a trial, all the more so from its now having in its favour the dicta of so many of our practical men.

2001. Mr Stevens has introduced a regulating air-door for furnaces, a section of which we show in fig. 787. The fire-door *a a* is provided with a series of apertures, which are closed and opened by the plate *b b*, moved by the handle *c*; when the apertures in both plates *a a*, *b b*, coincide, free admission of the air is secured. The air is admitted to the space, bounded by the semispherical part *d d*, through the apertures of which the air gains admission to the interior of the furnace. The part *d d* tends to keep the exterior door *a a* very cool.

Fig. 787.

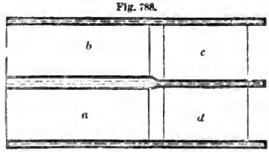


REGULATING AIR-DOOR FOR FURNACES.

2002. Coal, when heaped on a furnace or carelessly stoked, evolves a vast mass of opaque carbonaceous matter, containing much watery vapour, which cools the products below the temperature necessary to effect combustion, and thus sends off a large amount of fuel. By passing this cooled gas or opaque smoke in contact with a highly-heated surface, the temperature is at once raised to the necessary point, and combustion takes place. Hence the plans which have been introduced of furnace arrangements to effect this desideratum. Fire-brick bridges, when properly constructed, act in this way. The plan of having bridges as at fig. 784 is also a good one. The fire-bridge might be carried up to meet the boiler, and provided with apertures (vertical) of necessary area, through which the smoke would pass: the sides of these apertures being highly heated, would raise the temperature of the smoke, and promote its firing.

2003. *Alternate Firing.*—The system of "alternate firing" is one now largely introduced, with most beneficial effects. Two fireplaces, *a b*, fig. 788, are provided: while the contents of one are in a high state of combustion, and free from smoke, as in *a*, the fuel is supplied to the other furnace, as *b*; the smoke from this passes along the flue from *a*, and meeting the highly-heated air passing from the furnace *b* in the chamber *c*, the temperature of the smoke in the chamber *d* is raised, and ignition takes place. Advantageous as this method is, it possesses one defect—namely, from the distance which the heated smokeless air from *c* has to pass along the flue from *b*, it is robbed of a great deal of its temperature, and consequently the efficiency of the plan is in like proportion deteriorated. To obviate this defect, the plan of having a mixing-chamber immediately behind the fire-bars, into which the heated air from the smokeless furnace would pass at a very high temperature, has been carried out. This plan was, we believe, first adopted by Messrs Galloway of Manchester, and with the most complete success.

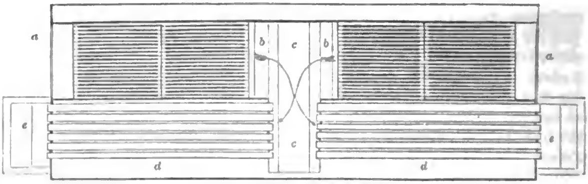
Fig. 788.



DOUBLE FURNACE-BOILER.

2004. *Smoke-consuming Boilers.*—The smoke-consuming boilers of W. B. Johnson, manufactured by Messrs Ormerod & Sons, engineers, Manchester, are becoming much used. An ingenious modification, well adapted for many localities, has a furnace at each end,—one being supplied with fresh fuel while the other is in a high state of combustion. In fig. 789 we give the plan of this boiler: *a a* the furnaces at each end; the products of combustion, after passing over the bridges *b b*, meet in the mixing-chamber *c c*, then pass through the tubes *d d*, right and left, to the smoke-boxes *e e*, and finally communicate with the flue leading to the chimney.

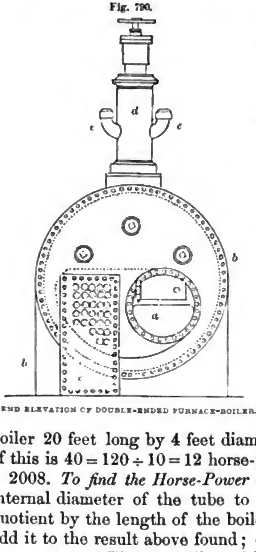
Fig. 789.



PLAN OF DOUBLE-ENDED FURNACE-BOILER.

2005. In fig. 790 we give an end elevation (the two ends are identical in appearance and arrangement) of this boiler. *a* is the furnace-door, *b b* the boiler, *c* the smoke-box, *d* the steam-pipe, *e e* the safety-valve pipes.

Fig. 790.



END ELEVATION OF DOUBLE-ENDED FURNACE-BOILER.

2006. Having discussed the subject of boilers, we now propose to describe those appliances which add to their efficiency and insure their safety. These appliances may be divided into two classes — first, those which have reference particularly to the maintenance of a due supply of water; second, those which have connection with the regulation and control of the steam.

2007. *Rule to find the Horse-Power of a Cylindrical Boiler.*—To find the horse-power of a cylindrical boiler with spherical ends and wheel-draught furnace, as in Plate XXXI., multiply the diameter of the boiler by the length, to this add one-half of the product, divide the result—which represents the flue surface in square feet—by ten, and the quotient is the horse-power. Thus a boiler 20 feet long by 4 feet diameter is of 12 horse-power, for $20 \times 4 = 80 + \frac{1}{2}$ of this is $40 = 120 \div 10 = 12$ horse-power.

2008. *To find the Horse-Power of an Internal-flued Cornish Boiler.*—Add the internal diameter of the tube to the external diameter of boiler, multiply the quotient by the length of the boiler—take half the product thus obtained, and add it to the result above found; divide the amount by 10, which will give the horse-power. Thus, a boiler with a tube 3 feet diameter, and boiler 5 feet external diameter, and 14 feet long, is nearly 17 horse-power ($16\frac{4}{5}$), for $3 + 5 = 8 \times 14 = 112 + \frac{1}{2}\,(56) = 168 \div 10 = 16\frac{4}{5}$.

2009. *To find the Dimensions of a Cylindrical Spherical-ended Boiler.*—Multiply the given horse-power by 10, from the product subtract one-third part of it; the result is the product of the diameter of required boiler multiplied by its length. This product may be made up by any convenient diameter and length—3 feet being the minimum diameter employed, as a less diameter will involve difficulties in manufacture and working. Thus the product of the diameter, multiplied by the length of a 6-horse boiler, is 40 feet, for $6 \times 10 = 60 - \frac{1}{3} = 40$. Boilers 10 feet long by 4 feet diameter, 13 feet 6 inches long and 3 feet diameter, will make up this product.

2010. The same rule here given will apply to single-flued Cornish boilers, with this difference, that the result shows the product "of the length by the sum of the external and internal diameters." Taking, as above given, a 6-horse power—this gives 40 feet. Now giving the diameter of the internal tube as 2 feet—less will not admit of proper fire-space—and the external diameter of boiler as 3 feet—the sum of these is 5, which, used as a divisor, gives 8 feet as the length of the boiler: $40 \div 5 = 8$.

2011. For the formulæ on which these rules are founded, we are indebted to Mr Imray's work on the *Steam Engine, and its Applications*, Houlston and Wright, 2s.; a work containing much valuable information on the subject.

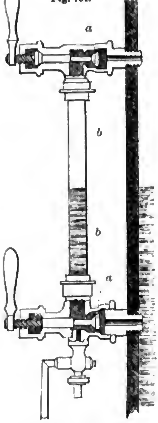
2012. *Apparatus for Supply of Water to Boilers.*—The *regular supply of water* to the boiler of a steam-engine is a matter of great importance. In those for condensing-engines it can be conducted with great certainty of effect, owing to the moderate degree of pressure under which they are worked; for as that does not generally exceed the pressure of a column of water 9 feet high, it is easy to establish a small cistern which is kept in constant supply, and which, by a self-acting hydrostatic arrangement, keeps the supply to the boiler perfectly uniform. The higher pressure under which the non-condensing engine works, prevents the same arrangement being followed in regard to its boiler, and no method of equal simplicity and certainty has yet been devised, though various methods are in practice. Some of the methods adopted are self-acting, or so called; and others depend entirely on the attention of the engine-keeper, which appears to be the safer of the two for engines not in daily use. Under this last method, the water-pump is understood to be in constant action, and to throw a superabundance of water; and when the boiler is observed to have got a sufficient supply—which is indicated by a float water-gauge—the discharge from the pump is turned off from the boiler, and thrown to waste or back to the well. This alteration of the discharge is effected by the attendant turning a stop-cock; but after a short practice, he is able, from observation, so to adjust the cock that the requisite supply shall go to the boiler, without entirely shutting the waste-cock. The apparatus for effecting this mode of supply is shown in fig. 2, Plate XXXI., where *s* is the stone-float, suspended by a wire *t* that passes through a small stuffing-box in the boiler-top. The wire is attached to a piece of chain that passes over the wheel *u*, and to the end of the chain is attached the counter-weight *v*. When the float and wheel, with its chain, are adjusted to the medium level of the water, an index or pointer *w* is attached to the wheel, pointing vertically; and any change in the level of the water will be indicated by a corresponding change in the position of the pointer to right or left. In this arrangement, the *power* that produces the indication is the difference of specific gravity between the water and the stone-float, after the float is balanced by the counter-weight *v*; and this being, in some cases, not of great amount, the apparatus is occasionally liable to get out of order, from the wire not passing freely through the stuffing-box.

2013. We have adopted a method that obviates this defect, which is also represented in fig. 2, Plate XXXI. In this arrangement, *w'* is a hollow copper ball, made securely water-tight. A wire stem rises from it, and passes freely through an iron tube *y*, of $\frac{1}{2}$-inch bore, which is fixed in the top of the boiler, passing 10 or 12 inches within it, and above it to any convenient height, serving as a guide for the stem of the float; to the top of this iron tube a strong glass tube is jointed at a', of about 1 foot high. The junction of the glass and the iron tubes, and the closing of the upper end of the former, are effected by a brass case, with screwed bottom and cap, which embraces the top of the iron tube and the whole of the glass tube, slits being made in opposite sides of the brass tube, through which the indication of the index can be read off. The index in this apparatus is the top of the float-stem, which being adjusted to length, and terminated in a small knob that will move freely in the tube, its indications of rise and fall are noted on a graduated scale on the brass tube.

2014. This method of *water-gauge* is still better accomplished, when circumstances permit of it, by the arrangement in fig. 2, Plate XXXI., by placing a small tube in the position $v'\ y'\ x'$, its lower end, shown by the dotted lines at v', being in connection with the water in the boiler, and its upper orifice x' with the steam, so that the pressure shall be equal on both ends. A piece of glass tube y' is placed in the middle of the channel of communication, or in such position that the level of the limits of range for the surface of the water may fall within the length of the glass; and the surface of the column in the tube will always indicate the same level as the surface of the water within the boiler. A graduated scale placed in contact with this, the zero being at the proper working level, will indicate with certainty the state of the water within the boiler.

2015. One objection to the form of gauge as illustrated in fig. 2, Plate XXXI., at $v'\ y'\ x'$, is, that should the gauge-glass be broken through accident, the steam and water are blown off, to the danger of the stoker, who may be standing near. To prevent this, and other inconveniences which are obvious, Mr John Smith, Traffic Street, Siddall's Road, Derby, has introduced a gauge-cock, in which valves *a a*, fig. 791, are provided. In the event of the glass tube *b b* breaking, the pressure of the steam and water causes the valves instantly to close. In addition to the water-gauge, gauge-cocks should invariably be applied; of these there are generally two, sometimes three. When two are used, one, on being turned, passes steam, the other water, to the atmosphere. The cock for water has the pipe reaching to a point below which it is dangerous to allow the water to be;—thus, when steam passes through this cock, it is an evidence that the water is below this point, and at a dangerous level; the feed-apparatus must therefore be looked to. The other cock has the pipe attached to it descending to a point at which water should not reach;—thus, if it emits water, it is an evidence that there is too much water in the boiler. When three gauge-cocks are used, two are for water at different levels.

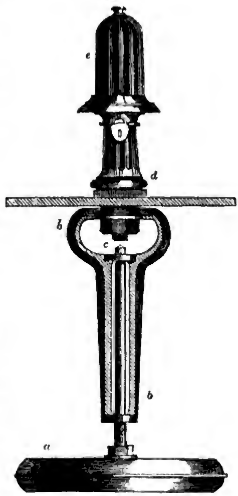
Fig. 791.



SMITH'S WATER-GAUGE

2016. *Haley's Safety-Signal for Boilers.*—A very effective appliance, by which the boiler itself gives the signal of its want of water, has been introduced by Mr Haley of Manchester. We give a representation of it in fig. 792. A copper float, *a*, screwed upon a brass spindle working in the guide *b b*, works loosely through a guide placed inside the boiler. The spindle is made hollow, and provided with an aperture near its upper end, by which steam is admitted to the interior of the copper float, thus equalising the pressure within and without the float. The upper end *c* of the spindle is made conical, which fits into a similar conical aperture leading to a steam whistle placed inside the ornamental cover *d e* outside the boiler; through this the steam is passed to the atmosphere. The arrangements of this safety-signal are admirably adapted to the end in view; there is not a part which is liable to become deranged; the action of the float is direct, its force is defined and invariable, and the signal is given by the simple expedient of allowing the spindle to fall away from the least possible surface of contact—a sharp edge.

Fig. 792.



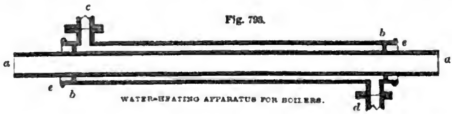
HALEY'S SAFETY-SIGNAL FOR BOILERS.

2017. These water-indicators, from the certainty of their effect, and the satisfaction they are capable of affording, at all times, as to the state of the water within the boiler to all parties concerned in its safety, ought to be universally adopted.

2018. Of the self-acting feeders for high-pressure boilers, it is not safe to trust even the very best without some auxiliary means of checking the results, such as the common gauge-cocks or the water-gauge. We have seen some of them so defective, that their boilers have been worked off almost to dryness, while it was imagined that all was going right, because the apparatus was throwing off what was considered surplus-water, while it had, in fact, been sending the whole supply past the boiler for hours. The consequences were, the destruction of the boiler, and a narrow escape from explosion.

2019. It is of great importance that the water sent into the boiler should have its temperature raised as high as possible before entering. This is effected in a very simple manner, and to a temperature of about 140°, by the apparatus, fig. 793, which may be placed in any position between the pump and the boiler that convenience may point out. *a a* is the waste steam-pipe, passing from the cylinder to the place of discharge in the chimney, or to the atmosphere. It is surrounded by the case *b b*, which should have an internal diameter of at least 1½ inch greater than the steam-pipe that it embraces; and the aperture *e* at

Fig. 793.

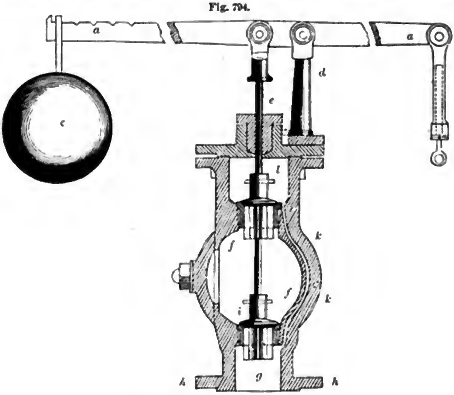


WATER-HEATING APPARATUS FOR BOILERS.

each end made steam-tight by a rust-joint. The small pipe through which the water is forced by the pump towards the boiler, is joined to the nozzle *c* of the case; and a continuation of the same being joined to *d*, is carried forward to the boiler, which it enters at *n*, figs. 1 and 2, Plate XXXI. While the waste steam, therefore, is passing through *a*, the cold water from the pump is forced into the chamber formed betwixt the steam-pipe and its case *b*, and in its passage along this chamber to the outlet *d* absorbs a portion of heat from the steam and pipe within, and so enters the boiler at the temperature stated above.

2020. *Differential Feed-Apparatus.*—In fig. 794 we give a sectional view

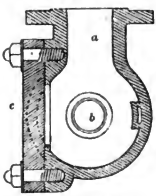
Fig. 794.



SECTION OF DIFFERENTIAL FEED-APPARATUS.

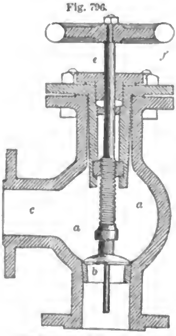
of "differential feed-apparatus," applicable to a form of high-pressure tubular boiler, and in fig. 795 a plan of the same. The lever *a a* is acted upon by the rod *b*, connected with the "float" inside of boiler; *c* the counter-weight balancing the float; *d* the standard on which the lever vibrates; *e* the valve-rod. The water is sent to the space *f f* by the pipe *a*, fig. 795; *g* the pipe leading to interior of boiler: the apparatus is attached to the boiler by the flange *h h*. When the pressure of the steam is great, the water forced up the feed-pipe *g* would have a tendency to open the valve *i*, without reference to the action of the float. To prevent this taking place, the water, instead of acting on *i*, passes up the side-duct *k k* into the space *l*, and acts upon the valve there placed, tending to keep it closed. As this valve is connected with the lower valve *i*, the motion imparted by the rod *e* being common to both, the pressure is equal both above and below the valve *i*; the float is therefore at liberty to act independently of the pressure on the boiler. Admittance is gained to the chamber *b*, fig. 795, in order to repair valve, or see if it is working properly, by taking off the flange *c*.

Fig. 795.



PLAN OF FEED-APPARATUS.

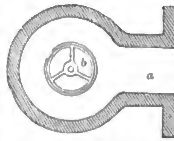
Fig. 796.



SECTION OF HAND FEED-APPARATUS.

2021. In fig. 796 we give a sectional view of the "hand feed-apparatus." The feed-water is supplied to the chamber *a a*, fig. 796, through the valve *b*, and passes to the "differential feed" in fig. 794, up the pipe *c*, which is connected with the pipe *a*, fig. 795. The amount of water passing through *b*, fig. 796, can be regulated, or the supply altogether stopped, by turning the screw and the spindle *e* by the wheel *f*—the amount of rise of the valve in its seat being dependent on the position of the screw. In fig. 797, *a* is the pipe corresponding to the pipe *c*, fig. 796, and *b* the valve. Fig. 798 shows the two in connection: *a* the pipe connected with the force-pump of the engine; *b* the horizontal wheel for working the screw, corresponding to *f*, fig. 796; the water passes to the chamber *c*, corresponding to *f f*, fig. 794, and passes to the interior of the boiler by the pipe *g*, fig. 794. Fig. 799 is another view of this apparatus: *a a* the boiler; *b b* the "feed" (fig. 794); *c* the pipe from force-pump, corresponding to *a*, fig. 798; *d* lever-wheel for turning screw, corresponding to *f*, fig. 796; *e e* lever; *f* counter-weight; *g* stuffing-box, through which the float-rod *h h* passes.

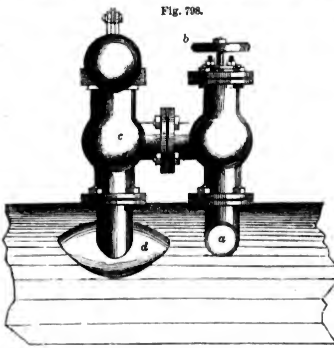
Fig. 797.



PLAN OF HAND FEED-APPARATUS.

2022. *Chimney-Damper.*—The combustion of the fuel in the furnace, and the consequent production of steam in the boiler, is generally regulated by a damper worked by hand. This consists of a flat plate working in a frame placed at the end of the flue leading to the chimney. By lowering the damper into the frame, so as to close the connection between the furnace-flues and the chimney, the draught of the fire is lessened, and also the production of steam.

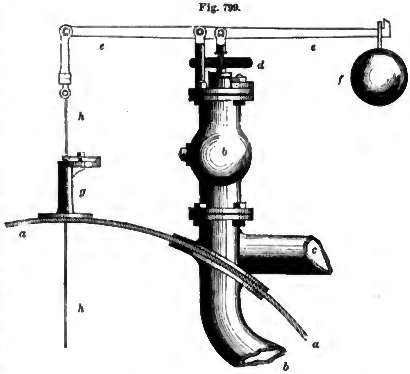
Fig. 798.



END VIEW OF FEED-APPARATUS.

2023. To save the attendant the trouble of mounting to the top of the boiler-furnace to operate on the damper, and in order, also, to keep it suspended at any desired point, the damper *a*, fig. 800, is hung with a chain *b b*, passing over two pulleys *c c*, and balanced by a counterpoise weight *d*. This weight generally hangs near the furnace door, so as to be within easy reach of the fireman. This apparatus is generally used for high-pressure boilers—but is defective, inasmuch as it is dependent for its operation upon the attention of the stoker. It is evident that, as the production of steam is dependent on the inten-

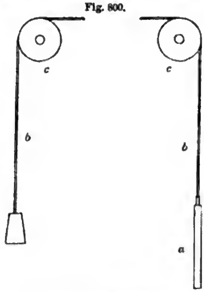
Fig. 799.



SIDE VIEW OF FEED-APPARATUS.

sity of combustion in the furnace, the most correct apparatus would be that in

Fig. 800.



CHIMNEY DAMPER ARRANGEMENT.

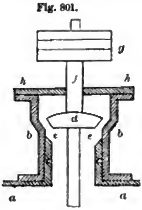
which the damper was actuated by the pressure of the steam itself. This has been attempted in various ways for high-pressure boilers; but, judging from the circumstance that comparatively few are met with in operation, it is to be supposed that they have not fully met the difficulties of the case. This plan, however, has been long adopted for low-pressure boilers.

2024. The principle on which self-acting dampers for high-pressure boilers are constructed is generally a plunger or piston, working in a small tube or cylinder attached to the boiler. The steam raises this piston, and depresses the damper when the pressure is too great, and *vice versâ*. The objection to this form is, that as soon as the pressure either rises or falls below the proper amount, the plunger or piston is raised, or allowed to fall so suddenly, that the damper is either closed or opened full, no gradation between the two extremes being obtainable.

2025. *Steam Regulating Apparatus.*—We now come to consider the second class of boiler appliances, namely, those connected with the regulation and control of the steam. Of these the most important is the safety-valve. This is shown at *q*, figs. 1 and 2, in Plate XXXI., and at *s*, fig. 3, in Plate XXXII.; but seeing the importance of this member, we shall go somewhat fully into the consideration of its operation and management.

2026. *Safety Valves.*—The simplest form in which these are made is represented in fig. 801. Let a pipe *a a*, *b b*, be bolted to the boiler-plate, and provided with a

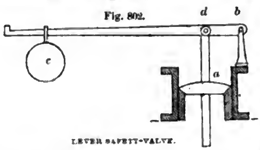
Fig. 801.



SECTION OF SAFETY-VALVE.

cover, and a large aperture in the side near the top, immediately below the cover. A brass tube *c c* is fixed inside the tube *b*, immediately above an aperture in the boiler-plate—the upper edge is made conical; into this a valve *d* fits, the two surfaces being ground together, so as to make a steam-tight joint. When the valve *d* is in its seat *e e*, the tail of the valve *d* is continued downwards a short distance, and the spindle *f* upwards, passing through the aperture in the cover and loaded with a number of weights *g*, according to the desired pressure. The steam presses on the under side of the valve *d*, with a tendency to raise it out of its seat; if the pressure increases so as to overcome the pressure of the weights *g*, the valve is lifted out of its seat *e e*, and the steam escapes through the aperture made in the pipe *b b*, below the cover. In place

Fig. 802.



LEVER SAFETY-VALVE.

of putting the weights as in fig. 801, the lever safety-valve in fig. 802 is adopted. In this form the load is placed on the valve *a*, indirectly through the intervention of the lever of the third kind, of which the fulcrum is at *b*, and the weight at *c*. By moving the weight *c* along the lever, the amount of pressure on the valve is changed; the farther the distance of the weight from the valve *a*, the greater the load on the valve.

2027. To calculate the pressure on a safety-valve, the following data are required: (1) the weight of the valve *a* (*a*), fig. 802; (2) the effective weight of the lever at the point *d* (*b*); (3) the distance from the point *b* to *d* (*c*); (4) the distance from *d* to the point where the weight *c* hangs (*d*); and (5) the weight of *c* itself (*e*); then multiply (*e*) by (*d*), divide the product thus obtained by (*c*), add to the quotient found (*a*) and (*b*), the result will be the pressure on the valve.

$$e \times d \div c + a + b = \text{pressure.}$$

2028. To graduate the lever *d c*—that is, to find points at which to hang the given weight to be used—the following data are required: The given pressure required on the valve in lbs. (*a*), the weight of the valve (*b*), the effective weight of the lever (*c*); distance of *c* to *d*, fig. 802 (*d*), the weight which it is proposed to use as *c*, fig. 802 (*e*); then from (*a*) subtract (*b*), add to the quotient (*c*), multiply the remainder by (*d*) and divide by *b* (*e*)—thus $a - b + c \times d \div e =$ the distance from the fulcrum *d*, fig. 802, to the point at which to hang the weight to give the desired pressure on the valve. The various distances thus found, representing various pressures, should be indicated by figures stamped on the upper side of the lever.

2029. The area of the safety-valve—that is, the surface it presents for the steam pressing on, or, what is the same thing, the area of aperture for the escape of the steam—is of great importance. The proportion generally allowed is a circular inch per 1¼ horse-power, or 0.8 of a circular inch per horse-power. To ascertain the weight to be used for loading a valve as in fig. 801, in order to give any required degree of pressure, square the diameter; multiply this by 7854, and multiply the area of the valve in square inches thus found by the pressure required; the quotient will be the weight (plus the weight of the valve itself), if applied directly, as in fig. 801.

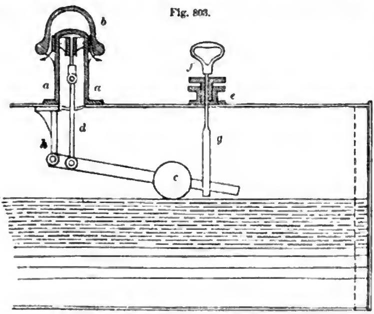
2030. A very excellent safety-valve is that known as the "Spring Safety-Valve." In this the load on the valve is regulated by the action of a spring, in a cylindrical case *t*, fig. 3, Plate XXXII., attached to the boiler. The end of the lever of the safety-valve is passed over the spindle of the spring, and is pressed down by turning the nut. The compression of the spring is regulated by the amount of turning of the nut, the index attached to the valve pointing out the amount of pressure on each square inch of surface of the valve. Thus, if the nut is turned down depressing the end of the lever, until the index points to the figures 40 on the scale, on the steam exceeding this pressure the valve will be lifted, and the steam escape.

2031. The area of the valve should be in proportion to the evaporative powers of the boiler, so as to allow the steam to escape as fast as it is generated; when it exceeds the desired pressure, if the size would be too great for one valve, this area should be apportioned to two—the required area being divided between them in equal proportions. The proportion of area we have given applies to low-pressure or condensing engines; the following is Mr Bourne's rule for ascertaining the area when there are two valves: Multiply the collective nominal horse-power of the engine by 25, to the product add 11.25; extract the square root of the sum, the result is the diameter of the safety-valve where two are used.

2032. One of these valves should be enclosed in a locked box, so as to prevent all tampering with the weights by the attendant.

2033. Mr Fairbairn's lock-up safety-valve is very useful. The valve is placed in a shell of thin brass, opening on a hinge, and secured by a padlock; it is of such a diameter as to allow the waste steam to escape easily. A weight to give the load in the valve may be fixed on any part to give the required pressure; this cannot be altered without getting inside the boiler. A handle is provided with a long slot, this passing through the boiler top through a stuffing-box; the safety-valve can be moved from time to time in its seat, to prevent it jamming or rusting in its seat; no extra load on the valve can be put by means of this handle. It will be necessary, when the boiler is cleaned out, to see that the attendant has not availed himself of the opportunity to add to or tamper with the weight. In fig. 803 we give a figure of Fairbairn's lock-up valve. *a a* is the valve cylinder or pipe, with brass cover *b*; the valve is weighted by the weight *c*, attached to the lever, the centre of which is at *h*; *d* the rod connecting the spindle of the valve with the lever; *e* the stuffing-box, through which the spindle of the slotted lever *f* works; *g* the handle by which the valve is made to move in its seat to prevent sticking.

Fig. 803.

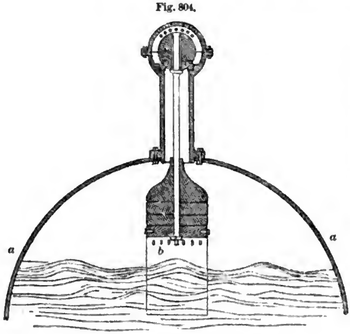


FAIRBAIRN'S LOCK-UP SAFETY-VALVE.

2034. The great danger to be apprehended in using the conical valve is its jamming or rusting in its seat, thus rendering it immovable. This is more likely to take place in the form of valve *d* in fig. 801, as the unequal contraction and expansion of the cover *h h* or spindle *f* may cause the spindle to get fast in the aperture.

2035. To obviate this sticking of the valve, Mr Nasmyth, the celebrated mechanician of Patricroft Works, near Manchester, has introduced what he terms the "Absolute Safety-valve," which effectually meets the difficulty. We give a representation of this in fig. 804. From this it will be seen that the valve *c* itself is spherical, resting in a conical seat. The spherical shape is the best for reducing the friction. The motion of the boiling water in the boiler *a a* acts upon a sheet-iron appendage *b*; and as this is connected to the valve by an inflexible rod, the swaying to-and-fro motion is communicated to the valve *c*. The valve resting in the seat, from being spherical, admits of a continual slight motion in its seat, equally in all directions, the result of the incessant swaying to-and-fro motion of the sheet-iron

Fig. 804.

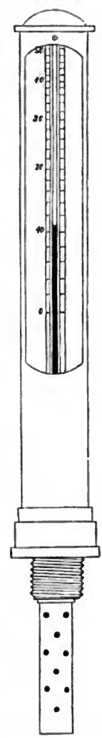


NASMYTH'S ABSOLUTE SAFETY-VALVE.

appendage acted upon by the constant ebullition of the water. The portion of the spherical valve and seat in contact being equal, maintains the close fitting of the parts. When the steam is up to the desired pressure, the valve rests on its seat—in a manner floating on the steam so lightly, that the pressure may be said to be equal to no pressure at all. This action, so desirable in a good valve, is frequently unattainable from the tendency which valves of the ordinary construction have to stick in their seats. The absence of all spindles and guiding parts in this valve, in addition to the great value it possesses as an obviator of the danger of "sticking," gives a high value to it as an efficient safety-valve.

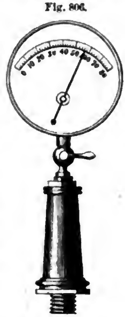
2036. *Steam Mercurial-Gauge.*—The safety-valve, when properly acting, affords in some measure a means of ascertaining the pressure of the steam in the boiler; its use in this way, however, is exceedingly limited; hence the necessity of adopting an appliance by which the pressure in the boiler can be ascertained by inspection at any desired moment: this is obtained by the use of the steam mercurial gauge. This ordinarily consists of a long iron tube, bent into the shape of a U, or an inverted siphon. One end is connected with the steam space of the boiler, and the other is open to the atmosphere. Mercury is poured into the tube, which, when uninfluenced by any action, stands at the same level in both legs of the siphon. But when steam is admitted to the end of the siphon attached to the boiler, the pressure on one surface of the mercury depresses it, and correspondingly raises the other. For every inch the mercury rises in the leg of the tube open to the atmosphere, an increase of pressure on the boiler of 1 lb. is indicated. To make this rising of the mercury evident, a small cork or wooden float should rest on the surface of the mercury in the open leg, this being connected with a scale properly graduated; the pointer or index pointing to 0 or zero when the mercury is uninfluenced by the action of the steam. As the tube is double, it is evident that every rise of an inch in the open leg indicates a difference actually of 2 inches in the level of the mercury. Correctly stated, a height of 2.04 inches of mercury is a counterpoise to 1 lb. of steam pressure. This siphon form of gauge is that which is generally adapted to low-pressure engines. A form for "high" pressure is shown in fig. 805. The mercury is contained in a close steam-tight cup; the steam is admitted to press on the surface of the mercury, and forces it up a tube; for each height of 2 inches of rise a pound pressure is indicated. One great advantage in the siphon gauge is, that if the steam rises to a dangerous pressure, the mercury is blown out of the tube, thus making it a most effective safety-valve, as there is then free way for the steam to pass from the boiler to the atmosphere.

Fig. 805.



MERCURIAL GAUGE FOR HIGH-PRESSURE ENGINES.

Fig. 806.



BOURDON'S STEAM-PRESSURE GAUGE.

2037. In fig. 806 we illustrate the form of pressure-gauge known as Bourdon's, in which the figures are indicated on a round dial. The steam presses on a spirally curved spring in the interior of the case, and actuates the finger.

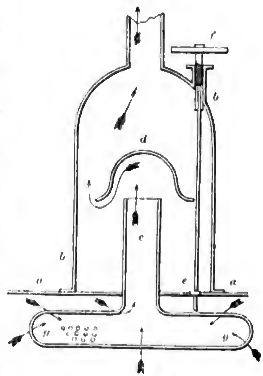
2038. *Fusible Plates.*—Another outlet for the escape of steam, when it attains to a high pressure, much recommended by some engineers of eminence in this country, and used in France to a considerable extent, is afforded by the contrivance known as the fusible plate. This is a plate composed of a combination of metals, alloys of tin and lead, with a small proportion of bismuth, in such proportions as will insure fusion at a temperature somewhere between 280 to 750 degrees. This plate is covered by a metallic perforated disc, which allows the metal to ooze through as soon as the steam has attained the temperature necessary to insure the fusion of the plate. It is found essential to the action of these fusible plates to protect them from the pressure of the steam, allowing them to be acted upon merely by its temperature; hence the plan of placing the fusible plate on a strong metallic perforated plate, which alone is subjected to the steam pressure. "In France," says Mr Fairbairn, "the greatest importance is attached to these fusible plates. . . . . In this country," he continues, "these alloys are not generally in use; but in this respect I think we are wrong, as boiler explosions are not so frequent in France as in this country; and high-pressure steam, from its superior economy, is more extensively used in France than in England." The fusible plate is also exceedingly valuable as a preventive of the dangers arising from the existence of surcharged steam. In boilers set on the oven plan, surcharged steam is most likely to be created, as the boiler-plate is sometimes exposed to the heat of the flues, from the water falling below its proper level. From the great accession of temperature thus attained by the steam, high danger of explosion ensues—a state of matters which is not indicated to any great extent by the safety-valve or vacuum gauge.

2039. Space prevents us from going further into the explanation of the phenomena attendant upon the existence of surcharged steam,—suffice it to say that it is a source of danger. To those desirous of going into the matter thoroughly, we would recommend a perusal of Mr Armstrong's shilling volume on *Steam Boilers*, section 28, p. 89.

2040. It is right, however, to state that these fusible plates are not in all cases to be depended upon. When the alloy is not homogeneous, the mercury is forced out of the plate, leaving the other material, which is not so easily liable to be fused. The practice of inserting a plug of lead in the boiler below water-mark, adopted in the case of locomotives, might be applied with greater advantage to agricultural boilers than these fusible plates.

2041. *Apparatus for Prevention of Priming.*—It is of great importance to have dry steam to work the engine with. Where the steam is immediately taken from the boiler by an ordinary steam-pipe, a considerable quantity of water is taken over with it—this being caused by the violent ebullition of the water, and the general deficiency of steam-room in many of our boilers. The priming thus caused in the cylinder is a great loss of power. In fig. 807 we give a figure of an appendage to a boiler for preventing this. Let *a a* be the boiler, *b b* a dome fixed on it, to which steam is admitted by the pipe *c*; a "dasher" *d* should be put above the aperture of the steam-pipe *c*: the water contained in the steam will be precipitated to the bottom of the dome, from whence, before starting the engine, or at proper intervals, it may be removed to the interior of the boiler through a pipe, the stop-valve of which is acted upon by the rod *e* and wheel *f*; the rod *e* passing through a stuffing-box in the top of the dome. Still further to insure the separation of the water from the steam, a modification of Hawthorn's "separator" may be adopted with advantage; a short length of pipe *g g* being attached to the pipe *c*; the end and body of this being perforated with holes, the steam must pass through these before gaining access to *c*. The pipe by which the steam is led to the engine is near *f*.

Fig. 807.



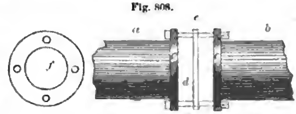
APPARATUS FOR PREVENTING PRIMING.

2042. *Encrustation of Boilers.*—We have already adverted to the bad effects of impure water for raising steam (par. 1959). The deposit resulting from these lines the inside of the boiler with a crust more or less difficult to remove, according to its constitutent parts. This "encrustation," as it is termed, is a fruitful source of mischief, and is the cause of great loss of fuel. Various remedies have been proposed for this: one—found to be very effectual, and, moreover, easily obtained—is "charcoal," prepared from hardwood broken into lumps of from a quarter to half an inch, the fine powder being carefully sifted. These lumps are put into the boiler, and act as an absorbent of all salts of lime and the alkaline earths, the salts of iron, and of nearly all other heavy metals. As the absorbent power is limited, it will have to be changed from time to time: about a bushel will protect a ten or fifteen horse boiler for some four weeks or so. Where salts of potash or soda are dissolved in the water, or in sea-water, the deposit will take place even with charcoal. The only remedy in this case is to use a "blow-off pipe," placed at the bottom of the boiler away from the fireplace. The water should be blown off at intervals through this pipe when the steam is up.

2043. *Joinings of Steam-Pipes.*—We now come to the methods adopted in fitting up steam-pipes under the various circumstances of the farm operations, whether for conveying steam from the boiler to the engine, or to the cooking apparatus for steaming food for cattle, &c.

2044. The flange-joint is shown in fig. 808. At each end of the pipes *a b*, circular flanges *c c* are cast with bolt-holes, generally four in number: a packing *d*, either of vulcanised India-rubber, plated hemp and white-lead, or a circular piece of millboard well smeared with red lead on both sides, is placed between the two flanges, and the whole screwed tightly together by the bolts and nuts *e e*. Vulcanised India-rubber washers are the best material for packing steam-pipes. Where plaited hemp or millboard are used, holes must be cut to allow the bolts to pass through—the packing assuming the form of two concentric circles as at *f*, the outer diameter being somewhat less than the diameter of flange of pipe *b*, the inner diameter being somewhat greater than the bore of pipe. A plaited hemp packing is made by plaiting a few strands of hemp to form a band, the width of which is a little less than the breadth from outside of flange of pipe to the bore, and the length of which will be sufficient, when curved, to form a ring of the diameter as at *f*.

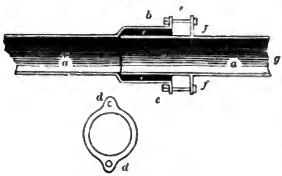
Fig. 808.



FLANGE JOINT.

2045. The faucet-joint or "socket," as it is sometimes termed, is shown in fig. 809. One end of each length *a a* is enlarged as at *b*, so that when the plain end of the pipe *g* is inserted in it, there is room left all round, as at *c c*, to insert the packing. Still further to secure a good steam-tight joint, snugs are sometimes cast on the pipes, as at *d d, f f*, and the two are brought close up by the bolts and nuts *e* as shown.

Fig. 809.

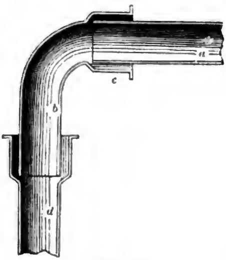


FAUCET OR SOCKET JOINT.

2046. Fig. 810 shows a circular junction of a horizontal pipe *a*, with a vertical one *d*; the curved portion *b* being provided with a faucet or socket, the plain end of *a* going into a socket *c* on the pipe.

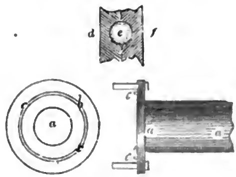
2047. Another method of joining pipes is sometimes used with good effects, if properly made. In the face of each flange a groove is turned, of depth sufficient to take in half the diameter of a wire ring. When the two flanges are brought close up to each other, the other half of the wire goes into the corresponding groove. In fig. 811, *a a* is the pipe, *a b* its section, *c c* the groove, *c′ c′* the wire ring; at *d e f* the joint is shown on a larger scale—*f* and *d* the flanges, *e* the wire. With this joint no packing is required.

Fig. 810.



CIRCULAR JOINT.

Fig. 811.



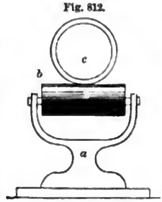
RING JOINT.

2048. *Cements for Steam-Pipes.*—The best packing for socket-pipes is the iron cement, composed of four ounces of sal-ammoniac to twenty-eight pounds of iron-borings: these must be free from dirt and rust. The ingredients are to be mixed together, and moistened slightly with water. As it spoils with keeping, only as much should be made as can be used at one time. The cement is forced between the two pipes by a caulking-chisel and hammer. This cement hardens very fast, and expands equally with the pipes. Sulphur is sometimes added, but it is not to be recommended, as it has a deleterious influence on the iron and on painter's work. In using this cement for the flange-joints, the skin of the iron should be broken; and if the surfaces be greasy, they should be well rubbed over with nitric acid, and well washed thereafter with water.

2049. Another cement for joining steam-pipes is the following: "Equal parts by weight of red-lead and black oxide of manganese in linseed-oil, to render it of a proper consistency." After the joints are packed, the bolts should be further tightened, especially if leakage takes place.

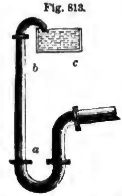
2050. *Steam-Pipes carried horizontally and underground.*—Where ranges of pipes are carried along horizontally—as when steam is conveyed from the boiler to the steaming apparatus — the great length of pipe, from the amount of expansion, is apt to loosen the joints and cause leakage. This is to a certain extent prevented, and the range allowed free motion during expansion, by being placed on rollers, as in fig. 812, where *a* is the standard for supporting the roller *b*, *c* the steam-pipe. Where pipes are laid horizontally, a considerable degree of inclination should be given to them towards the boiler throughout their length, so as to return the water of condensation to the boiler. Where they are placed at a lower level, as on the floor of a granary for drying purposes, the pipes may incline towards a small cistern placed at a lower level, or towards a curved pipe, as fig. 813, the steam pressure forcing the water up the pipe *a b* into the cistern *c*. A small valve is placed at *a*, opening upwards to prevent the return of the water in pipe *b*.

Fig. 812.



EXPANSION-ROLLER FOR STEAM-PIPES.

Fig. 813.



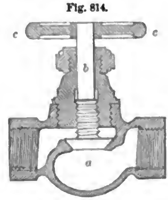
CISTERN FOR CONDENSED WATER IN STEAM-PIPES.

2051. In carrying steam-pipes underground from one apartment to another, across a yard, &c., great care should be taken to prevent the condensation of the steam in the range of pipes. These, throughout their whole length, should be carefully covered over with prepared felt, and placed in a box, which should be well rammed up with non-conducting materials, as sawdust, ashes, &c., the box being laid in a trench lined with brick, and cemented. All steam-pipes and boiler-surface exposed to the atmosphere should be also carefully covered with the prepared felt: a great saving of fuel is invariably effected by adopting this plan.

2052. Communication between steam-pipes is most frequently made by the ordinary plug or conical cock. This is very apt to leak from the unequal expansion of the plug, and the body or seat in which it works.

2053. A form of steam stop-valve, as shown in fig. 814, will be in every respect more satisfactory. The form here illustrated is that manufactured by Messrs T. Lambert and Son, Short Street, New Cut, Lambeth, London. *a* is the valve screwed down by the screw *b* and handle *c c*.

Fig. 814.



STEAM-COCK OR STOP-VALVE.

2054. We have been thus particular in giving directions as to steam-boilers and their fittings, as very much of the efficiency of an engine depends upon the condition of this department—being anxious, moreover, to take advantage of the limits afforded us to give the reader as fully as possible an extended notice of the various appliances, and the results of experience of practical authorities.

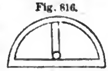
2055. *Varieties of Steam-Engines.*—We now propose to give illustrations of varieties of steam-engines in use, condensing and high-pressure; confining ourselves, in the first instance, to that class in which the *fixed* cylinder and piston are used, leaving for after consideration other varieties involving a departure, more or less decided, from this principle of action.

2056. *Steam-Engines with Fixed Cylinder and Piston.*—Steam-engines having the fixed cylinder and piston are divided into two classes—condensing and non-condensing, or high-pressure. We have already pointed out the distinction between high and low pressure steam in par. 1596. Though the condensing engine is seldom resorted to for agricultural purposes, there is no reason why it should not be considered the best and safest; and though the most expensive in first cost, yet when tear and wear of boiler, and expense of fuel, caused by the non-condensing engine, are taken into account, the difference will ultimately be very small, if any difference does exist. Perhaps the greatest obstacle to the adoption of the condensing engine on farms is the larger expenditure of water required for it; and though, considering the extensive drainage on all well-managed farms, one would expect a moderate command of water, yet the reverse of this is the real state of the case on a large proportion of arable farms. There can be little doubt, however, that, should the desire for condensing engines ever arise, the means will be found neither distant nor difficult to procure an adequate supply of that element which alone inherits the power. As the condensing engine is so seldom employed on the farm, it has been considered unnecessary to enter into any description of it in detail; but, at the same time, the few following remarks are thrown out for the information of those who may possess, or wish to possess, that more perfect machine.

2057. *The Condensing Steam-Engine.*—The low-pressure or condensing engine, for both names are equally appropriate, is distinguished from the non-condensing chiefly from the circumstance of the steam being condensed into water, immediately after it has performed the office of impelling the piston from the bottom to the top of the cylinder, or *vice versâ.* It is difficult to convey to the non-mechanical reader a just conception of this process of alternate action, but an idea of it may be conceived from the following statement: The vessel denominated the *cylinder* is closed, steam-tight, with a lid. The *piston* fits the interior of the cylinder, also steam-tight, and has a rod or stem attached to its centre, passing through a steam-tight stuffing-box formed in the lid. The pipe that conveys the steam from the boiler may be conceived to divide into two branches, within a chamber, before it reaches the cylinder, which they enter through the sides at top and bottom. At the point where these branches separate, they are brought into juxtaposition with a third opening, that stands in immediate connection with a second vessel called the *condenser.* A sliding concave cover is now so adapted to these three apertures as to be capable of opening a communication between the boiler and either of the two first, which we shall call A and C, A being in communication with the top and C with the bottom of the cylinder, while the third opening, B, leads to the condenser, but, by means of the slider, can be placed in communication with either A or C, that is to say, with the top or the bottom of the cylinder; and whenever a communication is opened between B and A, then C is open to the boiler; or, if B and C are made to communicate, then A is open to the boiler. For the more easy comprehension of this, see fig. 4, Plate XXXI. Suppose that B and C communicate, and that A is open to the boiler, and that the piston is at rest near the top of the cylinder, steam will rush through the pipe and open the passage A into the upper part of the cylinder, and by its elastic force will cause the piston to descend. When it has nearly reached the bottom of the cylinder, the slider is made to change its position, and now places the passage A in connection with B, while C is placed in communication with the boiler. The condensing vessel B, previously empty, and being kept constantly cool by the application of cold water, externally covering its whole surface, and internally entering it as a jet, receives the steam returning through A, and, finding no resistance to its passage into B, rushes thence, and is instantaneously condensed into water, leaving the upper part of the cylinder nearly a vacuum. At the same instant, steam from the boiler will flow through the pipe and passage C, which, acting upon the lower side of the piston, will cause it to ascend, and there being no resistance above the piston, it will be moved by the whole elastic force of the steam, which, in engines of this principle, will be about 16 lb. on the square inch of the boiler. When the piston has nearly reached the top of the cylinder, the position of the slider is again changed, so as to open the communication between the bottom of the cylinder through C and the condenser B, and likewise the communication between A, the top of the cylinder, and the boiler. The steam last introduced into C will now return into the condenser, and be again reduced to the state of water, while a fresh charge of steam from the boiler passes into A, by which the piston is once more made to descend. A few repetitions of such reciprocation would so fill the condenser as to render it ineffective; but to obviate this, the *air-pump*, so called, is added, as an essential appendage to the condensing engine. The air-pump is placed in connection with the condenser; its principle, as regards its connection with that vessel, is in effect the same as the common sucking-pump, but it is furnished with an additional valve above the range of its piston, communicating with a super-stratum of water during the ascent of the piston, and shutting off that communication during the descent; and its duty in this engine is to withdraw both condensable and incondensable matter from the condenser, so as to preserve in that vessel a vacuum as perfect as circumstances will admit of. By the help of the air-pump, then, a constant repetition of the reciprocations of the steam-piston is preserved, and motion continued through the action of the beam, crank, &c. After the condenser and air-pump, the other parts of this engine are essentially the same as in the non-condensing engine, excepting certain modifications in the apparatus of the boiler, arising from the inferior degree of steam-pressure employed in the one as compared with the other. The admission, or "distribution," as it is technically termed, of the steam to the cylinder, will be better understood by the following description and figure which illustrates the usual arrangement of the "long D valve" adopted in condensing engines.

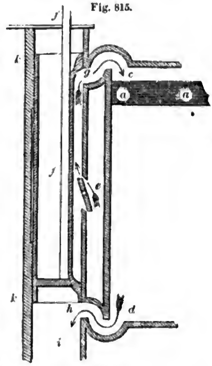
2058. "*Long D Valve.*"—In fig. 815 we give an explanation of the "long D valve." Let *a a* be the piston moving in the cylinder, *c* the upper port, *d* the lower. The slide-valve is semicircular, open from top to bottom as in fig. 816; the face *a* of the valve is kept up against the ports; the rod for working the valve is fixed at *f f*, fig. 815. The upper valve-face is at *g*, the lower at *h*; the steam is admitted to the space *e*, and from thence either to the upper or under side of the piston, according as the upper or lower port is open. In the figure the piston is just about descending; the upper port is opened to admit the steam through the upper port *c*, while the lower port *d* is quite open, admitting the steam to pass from the under side of the piston to the condenser, through the eduction-pipe *i* to the condenser, or to the atmosphere, if high pressure. Packing is placed between the back of the valve and the valve-casing at *k k*.

Fig. 816.



PLAN OF LONG D VALVE

Fig. 815.



LONG D VALVE

2059. In the condensing engine the *pressure* of the steam seldom exceeds 4 lb. on the square inch, more generally 2 lb., but this is to be understood as the pressure in the interior surface of the boiler above that of the atmosphere, which is acting externally on its surface with a pressure equal to 14 lb. on the square inch; in effect, therefore, the expansive force of the steam is equal to 16 or 18 lb. on the square inch, in any situation where the atmospheric pressure has been removed. We have endeavoured to show, in par. 2057, how this atmospheric pressure is destroyed or removed within the sphere of the condenser, which extends also to the top and bottom of the piston alternately, by the formation of a vacuum there, more or less perfect. When perfect, and the surfaces of all the parts with which the steam is in contact are kept at a temperature equal to that of the steam, the pressure on the piston will be 16 or 17 lb. on the square inch; this, however, can never be fully attained—and the loss of force from this and various other causes, arising from the friction of the working parts of the engine, through loss of steam by condensation, in passing to the cylinder, &c., has been ascertained to reduce the effective pressure to 9 lb. on the square inch of the piston,* which is the clear available power of the engine. This conclusion, applied to an engine for farm purposes, would indicate a cylinder of about 12 inches in diameter to produce 6-horse power, which is the power usually adopted on the farm. The consumption of steam by a cylinder of this calibre, after allowing for waste, would be 190 cubic feet per minute, or 11,400 per hour, and the water to supply this evaporation, at the temperature required in the boiler to produce steam of the pressure here supposed, would be 7.6 cubic feet, or nearly 50 gallons per hour. The water required for steam in the condensing engine is small in quantity compared to that required for condensation, and although the condensing process may be carried on with less than what may be considered a full supply, the water thus saved is acquired at a sacrifice of the steam power; in other words, the engine is caused to work with a less perfect vacuum, which, counteracting the impulse given by the steam to the piston, destroys a portion of the effective power. The quantity of cold water required for the most perfect practicable condensation is allowed to be about 24 times the quantity converted into steam, or 1200 gallons per hour, equal to 20 gallons per minute for a 6-horse power engine, and, including that for steam, 21 gallons nearly. With a view, therefore, of setting down a condensing engine, the very first point required to be ascertained is a *supply of water;* and unless this can be obtained in such quantity as above stated, it will appear doubtful whether or not it be advisable to adopt an engine of the kind. But the requisite supply of water may be considered in another point of view. It is seldom that a farm engine is required to work for more than one day of 12 hours continuously; the quantity of water required for that period would be 15,000 gallons, or upwards of 2300 cubic feet. A reservoir would thus be required, sufficient to contain at least one-half of this, which might be collected during the 12 unemployed hours of the 24; that is to say, if the constant supply were equal, in round numbers, to 1200 cubic feet in 12 hours, which is a little more than 10½ gallons per minute, this quantity, by storing it up during half the day, would supply the engine with full water during the remaining half. The capacity of the reservoir must necessarily be sufficient to contain this half supply, and, for this purpose, it would require 900 square feet of area and 2½ feet of depth, or any other suitable dimension, to bring out the capacity. By returning the water into cooling ponds—and nearly the whole of it can be returned, as is done in many cases, especially in towns—a supply greatly below this could be made to serve the purpose. In adopting such a system, however, the cooling ponds, to which the water is returned at a temperature varying from 100° to 130°, must have a surface so extended, that no portion of the water may be required to be returned to the engine until its temperature has been reduced to less than 70°. If condensation is attempted with water of a temperature much above 70°, either the quantity so applied must

* TREDGOLD *On the Steam-Engine*, p. 206.

be very large, or the temperature in the condenser must be high: the former implies a great consumpt of water, the latter a loss of effect from imperfect condensation. These are important considerations in the use of the condensing engine, where water is scarce; but to follow them out here is not our purpose.

2060. The inquiring farmer and mechanic will find ample details on this and all other points of the steam-engine in the works of Tredgold, Farey, Bourne, and others, which are devoted entirely to it.

2061. *The Non-condensing Engine.*—Steam-engines of this, as well as all the other species, are constructed in a great variety of forms, but for farm purposes, when stationary, they are chiefly confined to three—the beam, the crank over-head engine, and the horizontal cylinder engine; and, when portable, they are divided into two classes.

2062. *The Crank-Engine.*—In the non-condensing engine, the circulation of the steam from the boiler into and out of the cylinder is precisely the same as has been described for the condensing engine (par. 2057), until the steam arrives at that point where it entered the condenser. There being no condensing apparatus in the engine now under consideration, the passage that, in the former, led to the condenser, leads in this directly to the atmosphere, into which the steam is discharged at every half stroke of the piston. An engine on this principle is, therefore, a machine of extreme simplicity, compared with the former, and on this account chiefly has its adoption in agriculture become so general. Figs. 1 and 2, Plate XXXIII., are two views of this engine, the first being a front, and the second a side elevation, without the boiler. The motions of the steam have been already adverted to; and here it is now only necessary to observe, that the column *n o* becomes, in this arrangement, a part of the steam-pipe. The pipe leading from the boiler joins it at *n*, from whence the steam descends to *o*; and passing through that branch and the throttle-valve case *l*, it enters a channel that half embraces the cylinder, and opens into a small steam-chest that contains the slide-valve, or D slide. This, in fig. 1, is concealed behind the cylinder, and in fig. 2 it is also hid behind the column; but in fig. 4, Plate XXXI., the arrangement is seen in section, as will afterwards be described. The steam-chest covering the slide being thus in communication with the boiler, the steam, from its elasticity, is always ready to flow into any channel that is opened for it. Hence, as the slide is moved alternately from off the passage leading to the upper and to the lower ends of the cylinder, the piston is made to reciprocate between the top and bottom. At every change of the slide, the passage leading to the atmosphere is put in communication with the top or with the bottom of the cylinder, and the steam—which had, in the previous stroke, done its duty on the piston—is drawn off and discharged through a channel corresponding to that by which it entered; and, passing through the branch *q* into the column *q r*, it is discharged into the atmosphere by the pipe *r*, which frequently terminates in the chimney.

2063. To follow out, in the first place, the results of the circulating system in this engine, as has been done in the condensing engine in par 2057, we have to consider the amount of power from a given area of piston and given pressure of steam. Unfortunately, there is a wide difference of opinion as to the rule for determining the power of non-condensing engines; for, while some hold an area of 80 circular inches of piston as equivalent to 6-horse power, others allow an area of 120 of the same inches as requisite to bring out the power of 6 horses. It is more than probable that these discrepancies have arisen from the circumstance of the motive power, in this case, being of such a variable nature; for it is so easy to change the force of steam in the boiler from 25 to 30 or 35 lb. on the inch, that the real power becomes quite a nominal quantity. There appears to us a source of error, also, in the rules given by writers for finding the power of non-condensing engines, by their not making proper allowances for that portion of the original force of steam in the boiler which is lost by friction of parts, &c. Thus, Tredgold, in his rule for finding the power,* gives a cylinder of 11 inches diameter for 6-horse power, with steam of 24 lb. in the *circular* inch, which is equal to 30 lb. on the square inch. But experience goes to show that this is too low a calculation; and by a rule which we conceive to be near the truth, an engine with 11-inch cylinder is nearly 7-horse power. What we conceive to be the ground of this error is the allowance made for the resistance of the atmosphere to the steam, as it is discharged from the cylinder. From the rapid discharge of the steam into the atmosphere, and its natural condensation there, it may be inferred that an artificial atmosphere is formed, which extends as far as the limits of this discharge, and of considerable rarity, exerting an influence, as near as we can estimate, equal to only one-half the natural pressure of the atmosphere, or 5.75 lb. on a circular inch. With this element, and taking the loss of expansive force between the boiler and the piston at the usual calculation of 4-tenths of its pressure in the boiler, leaving 6-tenths as the effective pressure,† we have the following rule.

> Multiply the square of the diameter of the cylinder in inches into 6-10ths of the entire pressure of the steam in the boiler in lb. on the circular inch, *minus* half an atmosphere, or 5.75 lb., on the circular inch; and the product by the velocity of the piston in feet per minute. The last product is the power of the engine in lb. raised one foot high per minute; and for the horse-power divide as usual by 33,000. For example,

> Let the cylinder be 9 inches diameter, the length of stroke 20 inches, and the number of strokes per minute 84, being equal to a velocity of 214 feet per minute for the piston, and the pressure in the boiler 25 lb. on the circular inch, equal to 32 lb. on the square inch nearly; then, $(.6 \times 25) - 5.75 = 9.35$; and

$$\frac{9^2 \times 9.35 \times 214}{33,000} = 5\text{-horse power nearly.}$$

2064. By the rule given above for the power of non-condensing engines, a cylinder of 10 inches diameter, with a pressure of 25 lb. on the circular inch, and making 60 strokes per minute, is equal to 6-horse power; and the piston will move at a velocity of 214 feet per minute, making the consumpt of steam, allowing for waste, equal to 128 cubic feet per minute, or 7680 per hour. The proportion of water to steam, consumed at this pressure, is about 1 to 850, or a little more than 9 cubic feet of water, being about 57 gallons per hour for the supply of the boiler. This calculation is stated merely to show how small the quantity is that suffices for a non-condensing engine of 6-horse power.

2065. The complicated passage of the steam through the cylinder has been alluded to in par. 2057; but, considering how important it is that the farmer should have a competent knowledge of the machinery with which his business is carried on, we shall endeavour to render this part of the subject still more definite by a reference to fig. 4, Plate XXXI. This is an enlarged section of the steam

* TREDGOLD *On the Steam-Engine*, p. 84. † Ibid.

cylinder and slide-valve, with its case. *a* is the cylinder, *b* the piston, *c* the piston-rod, and *d* the cylinder cover, with the stuffing-box through which the piston moves, steam-tight; *e* is the steam passage to the upper side of the piston, and *f* that to the lower side: these passages lead from the steam-chest *g*. The steam-chest or valve-case is attached to the cylinder in such a way as to embrace the three openings, A, B, C. The case *g* contains also the slide *h*, to which is attached the slide-rod *i*, passing through its stuffing-box in the cover of the case. The slide-rod is acted upon by the eccentric on the crank-shaft, which is so adjusted as to move the valve at the precise time and place required for the due admission and emission of the steam to and from the cylinder. In the figure, the slide is in the position that connects the opening C with the opening B; or, in other words, the passages are open that allow the steam under the piston —which is now upon its descent—to escape in the direction of the arrow, through B, into the atmosphere; while the steam from the boiler enters the case by the aperture *k*, and, passing directly to the opening A, passes through *e* into the cylinder, causing the piston to descend. When the piston has reached near to the middle point of its stroke, the slide begins to move from its present position; and when the piston has reached within 1 or 2 inches of the bottom —for this varies according to the views of the engineer—the orifice A will have been shut off from its connection with the case *g*, and immediately thereafter the orifice C is opened into *g*, the connection between C and B having, in the short interval, been cut off by the movement of the slide; and previous also to the commencement of the piston's ascent, the communication between B and A is opened by the same movement, permitting now the steam above the piston to escape through *e* and B to the atmosphere. This new position of the slide causes the *ascent* of the piston, and a repetition of the movements in the reverse order produces again the descent of the piston, and so on.

2066. To return to the structure of the crank-engine, the parts of which it consists may be described as follows: *a a*, Plate XXXIII., is the wall separating the engine-house from the barn, *b b* the level of the engine-house floor, and *c c* the sole-plate on which the superstructure of the engine is raised. The sole-plate is bolted down to a mass of solid masonry, to give it perfect stability. The masonry usually consists chiefly of two blocks of stone, each about 5 feet in length, 2 to 2½ feet in breadth, and at least a foot in depth; these are laid upon a foundation of coursed masonry, from 1 to 2 feet in depth, as the locality may require, and the bolts pass down through all. The two columns *d* are secured to the sole-plate by two of the above-described bolts, which take hold of the column by means of strong cotterels passing through the column and the bolt; which last is secured under the masonry by a screw-nut or by a cotterel. The tops of the columns are secured in various ways, but in the present case by means of a beam of cast-iron *e e*, forming an entablature which extends across the engine-house and rests at each end in the walls; the connection between this and the columns being also effected by bolts and cotterels. A guide-bar *i* extends between the two columns, through which the head of the piston-rod passes, to preserve its parallelism; and this constitutes the whole framework of the engine. The working parts remaining to be described consist of the connecting-rod *h*, which joins the piston-rod with the crank *k*, which last is firmly fixed upon the crank or main shaft *l*, which has its bearings in the beam *e* and wall *a*. The fly-wheel *m* is placed upon the crank-shaft, its purpose being to equalise the motion of the engine. It is necessarily of considerable weight, and the diameter should not be less than 8 feet; the section of its rim being equal in area to 16 square inches, yielding a total weight of from 14 to 15 cwt.

2067. Tredgold has given a rule for determining the *weight of a fly-wheel* in the following terms: "Multiply 40 times the pressure on the piston in pounds by the radius of the crank in feet; divide this product by the cube of the radius of the fly-wheel multiplied into the number of its revolutions per minute; the result is the sectional area of the rim of the fly in inches." To apply this rule to the case before us, we have the pressure on the piston, which is 10 inches diameter, equal to $10^2 \times 25 \times .6 = 1500$ lb., radius of the crank .91 foot, radius of fly-wheel 4 feet, and making 60 revolutions per minute, then

$$\frac{1500 \times 40 \times .91}{4^3 \times 60} = \frac{60{,}000}{3840} = 15 \text{ inches nearly,}$$

which gives a weight of rim equal to about 11 cwt., and, with the eye and arms, will amount to 14 or 15 cwt., as before stated.

2068. The crank-shaft carries also the two eccentrics at *y*, the one for the pump-rod *z*, to which is jointed the plunger *a′* of the pump for supplying water to the boiler. The other eccentric moves the slide-valve rod seen between the column and the pump-rod; and the shaft likewise carries the pair of bevel-wheels that give motion to the governor *t*. The governor is supported at bottom on the bracket *u*, and at top runs in a collar of the V bracket *v*, bolted upon the beam *e*.

2069. The essential parts of the *governor* are the two oblique rods *b′ b′* with the balls *c′ c′* attached at their lower extremity; and these being suspended by a joint on the vertical axis *d′ d′*, the whole is rendered capable of revolving horizontally upon that axis. In this form it is known as the conical pendulum, and was first applied as a regulator of the steam-engine by Watt. If the vertical distance between the points of suspension of the rods, and the plane in which the centre of gravity of the balls and rods revolve, be made the same as that of the common seconds pendulum, and the balls be made to revolve, they will have no tendency either to rise or fall by their centrifugal action, if each revolution is performed in two seconds, being the time that a common pendulum takes to make a vibration forward and back to the same point, or 30 revolutions in a minute. It is this principle that gives the conical pendulum value as a regulator; for if the machine that gives motion to the governor is accelerated, from a reduction of resistance or other causes, the revolving balls partake of the acceleration, and the centrifugal action, thus generated, gives them a tendency to fly off from the centre of revolution. This outward motion is converted into the means of regulation, for while the balls and rods extend their circle of gyration, they act upon the two jointed arms *e′ e′*, which meet in the sliding piece *f′*, where they are also jointed, and *f′* is drawn upward. A lever is frequently attached to *f′* by a fork; but in this example the lever *w* is applied to the collar *g′* above the joint of the rods, and this collar being connected to *f′* by two slender side-rods, they move together, and the lever *w* being suspended near its centre *h′*, has the opposite extremity jointed to the rod *x*, the lower end of which acts upon the lever of the throttle-valve. In small engines, the arms of the governor are never made equal in length to the seconds pendulum, but of such length as will accord with velocities of 40 or 45 revolutions per minute; and the length of arm to produce this is easily found by the common rule for the length of pendulums,—their vibrations being as the square root of their length,—and the revolutions of the conical pendulum being half the number of vibrations of a common pendulum of the same length.

2070. The *throttle-valve*, to which the effects of the governor are directed, is a thin circular plate of metal, having an axis fixed across its diameter, and is nicely fitted into the steam-way, passing through the case *p*. The spindle passes through the sides of the case steam-tight, and carries on one end a small lever by which the valve can be turned; and the lever is put in connection with the lower end of the rod x. The extension of the balls of the governor acting on the slide f', and from that, through the lever and rod w and x, depresses the lever of the valve, and by thus turning the valve, reduces the steam-way, and prevents further acceleration of the machine.

2071. In *setting down the engine*, we have to consider the space necessary to receive it. This, in the direction of the barn wall, need not be larger than 8½ feet, or a few inches more than the diameter of the fly-wheel; the breadth in the other direction should not be less than 8 feet, but may extend to 9 or 9½ feet. In almost every case, this form of engine is the most commodious for application to a thrashing-machine, especially in regard to the dimension of height; for the height that the crank-shaft stands above the floor of the engine-house will generally bring it near to the large spur-wheel, which, though not in all thrashing-machines, is yet to be found in a large majority of them. This is supposing that the floor of the engine-house is nearly on a level with the barn-floor, which will generally be the case, unless artificially changed.

2072. *The Beam-Engine.*—In reference to the beam-engine, the mode of action of the steam in its passage to and from the engine, the quantity of steam and of water, the power, the regulating and governing, and, indeed, every essential principle, being common to it and the crank-engine, par. 2062, it becomes unnecessary to say more than merely to point out the difference in construction. Figs. 1 and 2, Plate XXXIV., represent the beam-engine of 6-horse power; fig. 1 being an elevation, and fig. 2 a plan: the same letters refer to both figures. The sole-plate, *a a a*, is bolted down to the seat, consisting of solid masonry, as described in par. 2066; but in this case the pit extends to a distance equal to that between outside and outside of the end columns, the width being about 20 inches, and the depth varying from 3 to 7 feet, according to the position of the barn and the engine-house, and of the large gearing. The bolts that secure the sole-plate lay hold also of the columns *b b*, fixed with cotterels: *c* is the entablature frame, bolted to and securing the heads of the columns. To this is bolted the carriage of the main centre of the engine-beam *h h*. A small portion of the wall that separates the barn from the engine-house is at *d*. The cylinder is *e*, *f* the piston-rod, and *g g* the parallel motion,—the medium of connection between the piston-rod and the beam. *A parallel or rectilineal motion* of some sort is a necessary appendage to the beam-engine; for as the extremity of the beam, in its vibration, describes an arc of a circle, while the piston-rod must describe a rectilineal course, a direct junction of the two is incompatible; hence the absolute necessity of some medium being interposed to allow the two to act in concert. This object is attained by the parallel motion here figured, which was, in its original form, the invention of Watt; and though it appears under various modifications, they may be all reduced to one principle, the object of which is to procure a point or points in the construction that shall describe a straight line. In the figure, the point to which the piston-rod is attached, and also that to which the pump-rod *h'* is attached, possesses the property within certain limits. Though this arrangement of parts goes by the name of the parallel motion, it is only within certain limits that the motion of the points alluded to preserves a strictly rectilineal course; and towards, but especially beyond the limits, the deviations are very considerable, going on with increasing deviation, till the motion of the point ends in a returning curve or loop. Notwithstanding this apparent defect, the motion is sufficiently perfect for all practical purposes, provided the longitudinal axis of the beam *h*, in the extreme points of its vibrations, does not subtend an angle exceeding 36°.

2073. That end of the beam which is opposite to the parallel motion has the connecting-rod *i* jointed to it, and the latter is connected to the crank *k* by means of the crank-pin or journal, which turns within a bearing in the lower end of *i*. The crank is firmly attached to the main or crank-shaft *l*, which is supported in two plummer-blocks, one in the sole-plate *a*, and one upon the wall *d*, and it also carries the fly-wheel *m*, of dimensions similar to that formerly described in pars. 2066 and 2067. As will be seen in the figures, the fly-wheel in this engine is nearly half immersed in a pit formed for its reception.

2074. Regarding the distribution of the steam in this engine, it enters by the pipe *n*, fig. 2, Plate XXXIV., passing through the throttle-valve case *p*, and after performing its duty in the cylinder, is discharged through the pipe *o* into the atmosphere, either directly or through the chimney. The lever of the throttle-valve is *q*, and *r* is the top of the slide-valve case; *t t* the eccentric rod, acted upon by an eccentric placed on the crank-shaft, over which the circular extremity of the rod *t* passes, and by its alternate action causes the vibrations of the wiper by the arm *u*, fig. 1, and whose opposite arms are jointed to the cross-head at *v* of the slide-rod *r*. The small bevelled wheel *w*, on the crank-shaft, gives motion to the upright shaft *y* of the governor; and the saddle-shaped carriage *x*, which spans over the crank-shaft, forms a foot-step for the governor-shaft, while its upper journal is supported in a bracket projected from the entablature *c*, but is hidden from view in the figure. The governor is partially seen at *z* in fig. 1; its construction is the same as that described in par. 2069, and its motions are communicated to the safety-valve through the rods *a′* and *b′*.

2075. The *pump* for supplying water to the boiler is attached to the sole-plate by means of the cross-bar *a a*, fig. 2; and *c′* is the pump-chamber, *e′* the case of the upper valve, *d′* the case of the lower, and *f′* is the suction-pipe proceeding to the well or cistern, while *i′* is the pipe which conveys the supply to the boiler. Pumps of this kind are generally worked on the principle of forcing, with a solid piston or plunger, which is here represented at *g′*, and is connected by a socket and key-joint to the pump-rod *h′*.

2076. *Setting on and Stopping the Engine.*—The setting on and stopping the non-condensing engine is an exceedingly simple operation; and its simplicity is even simplified by the addition of a cock or valve on the steam-pipe, which is very frequently adopted, and in that case the throttle-valve is not required to be so accurately fitted as where no stop-cock is employed. To *set on the engine*, the steam must first be brought up to the requisite degree of pressure. When this is accomplished, which is known by the safety-valve rising so as to allow the escape of steam, the stop-cock, if there is one, is opened, the throttle-valve being also open; the steam is admitted both above and below the piston, by moving the slide with the handle of the wiper-shaft *u*, to heat the cylinder, the eccentric-rod *t* being at the time disengaged from the shaft. This done, the *gab* of the eccentric rod is laid upon the arm of the wiper-shaft; and if the crank is in a horizontal position, the engine may start off without assistance; but if it does not move, the fly-wheel is to be pushed round a few feet, or until the crank has once passed the *centres*, when it will move on freely. If no resistance is upon the engine, the throttle-valve should be put nearly shut, but as soon as the resistance comes—the commencement of thrashing, for example—the throttle-valve lever *q* is to be connected to the vertical rod *b′*, and the work will proceed regularly.

2077. In *stopping*, where there is a stop-cock, the shutting of it puts a stop to further motion, except what the momentum of the parts may continue to give out for a few seconds. Where there is no stop-cock, the first step is to disengage the throttle-valve lever *q*, and close the valve; and immediately after disengaging the eccentric rod *t* from the wiper-shaft *u*, the engine will stop. It is advisable to keep the eccentric rod *t* disengaged at all times when the engine is standing.

2078. As the engine-house is seldom accessible directly from the barn, there ought always to be means established for communicating a signal between the two places; and this should proceed from the chief of the operation—the person who feeds the machine. As there can be but two propositions to make—to set on and to stop—one signal is sufficient, and a *bell* seems to be the most convenient medium of communication.

2079. *Condensing Beam-Engine.*—In Plate XXXV. we give a series of figures illustrative of the arrangements of a 12-horse beam condensing steam-engine. Fig. 1 is the side elevation, fig. 2 the plan, fig. 3 the plan of entablature, fig. 4 an end elevation at cylinder, fig. 5 an end elevation at connecting-rod, and fig. 6 plan of beam.

2080. The foundation *a a*, fig. 1, is of stone or brick; *b b* the cylinder; *c* the piston; *d′ d′*, fig. 4, the cross-head and side-rods for working the valves; *d d*, fig. 1, the valve-casing; *e* the slide-valve; *f* the eduction-pipe leading to the condenser *g*, placed in the cold-water cistern *h h*; *j k* the air-pump; *l* the hot-water cistern; *m* the hot-water feed-pump; *n* the cold-water pump, to supply cistern *h*; *p′ p′* framing; *p p* entablature; *q q* beam vibrating on the centre plummer-block *r*; *s s* the connecting-rod; *t* the governor; *u* the crank; *v* the eccentric, for working the valves. In fig. 6, the plan of beam, *a a* is the main centre; *b b* the studs to which the cold-water pump-rod *y*, fig. 1, is fixed; *c c* the studs to which the hot-water pump-rod *x*, fig. 1, is fixed; *d d*, the studs for the rod *w*, fig. 1, of the air-pump; *e e* the studs of the main links 1, fig. 1; and *f f* those of the connecting-rod *s s*, fig. 1. The same letters of reference apply to all the figures.

2081. The operation of the engine remains now to be described. The steam, after working the piston, say during the up-stroke, passes down the eduction-pipe to the condenser, where it comes into contact with the jet of cold water projected into its interior: a vacuum is thus formed below the piston, which has reached the top of the cylinder. By the action of the eccentric, the slide-valve is made to open the upper steam-port, through which the steam is admitted above the piston into the vacuous space below the piston; the piston descends, the upper steam-port is thus closed, and a communication made through it with the condenser; the steam from above the piston rushes through the port down to the eduction-pipe into the condenser. A vacuum is now formed above the piston, and by the eccentric the slide-valve is made so as to open the lower port for admission of steam, when the same action goes on as just described. By this means an up-and-down motion is imparted to the piston and piston-rod. This reciprocating motion is imparted to the working-beam, which is poised or balanced on its centre, and the reciprocating movement is changed into a continuous circular one, by connecting the end of the beam furthest from the cylinder to a crank, by means of a connecting-rod. As there are two points in each revolution of the crank, termed the "dead points," in which the reciprocating movement of the beam and connecting-rod has no tendency to make the crank revolve, a heavy fly-wheel is fixed on the crank-shaft, the momentum of which, being derived from the action of the crank when receiving the full force of the engine, carries round the crank past the "dead points," and thus keeps up a continuous motion (more or less perfect) of the crank-shaft and fly-wheel. In fig. 1 the crank *u* is midway between the "dead points." When the piston is at the bottom of the cylinder, the tendency of the connecting-rod is to pull the crank upwards out of its bearings, while the tendency, when the piston is at the top of the cylinder, is to press it downwards. While the ends of the beam describe portions of a circle, the piston-rod is made to move in a straight line by means of the beautiful mechanism known as the "parallel motion," as already described in par. 2072. The vibrating motion of the working beam imparts a reciprocating motion to the rods of the hot and cold water pumps and the air-pump, by which the pistons or plungers of the same are worked. After being condensed, the water of condensation resulting is withdrawn from the condenser by the air-pump, and delivered into a hot-water cistern, from which it is pumped by the force-pump, and delivered to supply the boiler. To regulate the supply of steam to the cylinder, the contrivance of the "governor" is used. When the engine is working too fast, the balls, from the centrifugal force generated by the revolution of the spindle to which they are attached, fly outwards, and thereby move a lever, or series of levers, by which the valve is closed (more or less), by which the steam is admitted to work the cylinder. On the engine working more slowly, the balls drop inwards, and the lever opens the valve. Such is a general explanation of the movements of a condensing beam steam-engine.

2082. *Horizontal High-Pressure Engine.*—In Plate XXXVI. we give figures of one of the third class of stationary agricultural engines—namely, a horizontal engine, manufactured by Messrs Clayton and Shuttleworth of Lincoln. Fig. 1 is a side elevation, fig. 2 a plan, fig. 3 an end elevation at cylinder end, and fig. 4 an end elevation at crank end.

2083. In fig. 1, *a a a a* is the foundation or engine-bed; *b b* the sole-plate framing, bolted securely down to the bed; *c c* the cylinder; *d* the cylinder-gland or stuffing-box; *e e* the piston guide-bars or slides; *f* the piston-rod cross-head; *g* the lubricating cup for the guide-bars; *h* the piston-rod; *i i* the connecting-rod; *j* the crank; *k k* the eccentric rod, for working the steam-valve; *l* the eccentric for working the connecting-rod *m*, jointed to the plunger of the pump *n*, which supplies the boiler with water; *o o* the pedestal, in which the crank-shaft *p* revolves; *q q* the fly-wheel; *r r r* a driving-belt passing round a pulley on the fly-wheel shaft, and over a second pulley *s*, driving the gearing of the governor *t t t*; *u* the steam supply-pipe. In fig. 2 (the plan) the same letters denote similar parts in fig. 1; the additional letters *v v* showing the valve-casing; *w* the lever of the throttle-valve; *x x* the pedestal, supported by the wall *y y*, for supporting the extremity of fly-wheel shaft *p p*; *q q* the fly-wheel. In fig. 3, *a a* is the engine-bed; *b b* the sole-plate; *c c* the cylinder; *d d* the valve-casing; *e e* the steam supply-pipe; *f* the throttle-valve handle; *g g* the fly-wheel shaft, supported by the pedestals *h h*; *i* the eccentric, for working the plunger of the pump *j*; *k k* the fly-wheel. In fig. 4, *a a* is the engine-bed; *b b* the sole-plate; *c c* the connecting-rod; *d d* the crank; *e e* the fly-wheel shaft, supported by the pedestals *f f f*; *g g* the fly-wheel; *h* the governor; *i* the eccentric, for working the plunger of the pump *j*; *k* the eccentric, for working the slide-valve.

2084. *Portable Steam-Engines.*—Having now described and illustrated various examples of the class of *stationary*, we come to describe those of the next class, or *portable* engines.

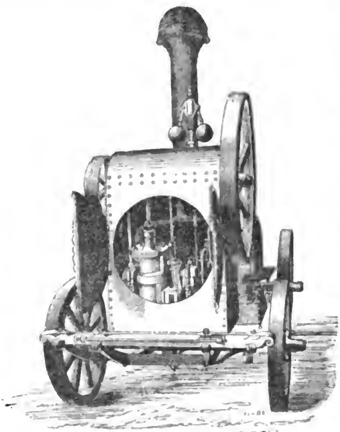
2085. Portable engines are those in which all the parts are self-contained, requiring no fixed or permanent location, but can be easily moved from one place to another. They may be divided into classes: 1st, Those which are designed to be worked under cover, but are so far portable as to be easily removed from one part of an apartment to another, or from one apartment to another; 2d, Those removable from place to place, from one part of the farm to another, and to be worked in the open air or under cover indifferently. As an example of those to be worked under cover, we present two figures in Plate XXXVII. of a crank over-head engine, manufactured by Mr Wm. Walker, engineer, Lower King Street, Manchester. Fig. 1 is a front, and fig. 2 a side elevation: the letters refer to both figures. The framing *a a* is square in section, tapering upwards; the base-plate *b* is continued forwards, to afford a bed-plate to which to secure the cylinder *c*; the guide-bars *d d* are bolted to the framing at their upper and at their lower extremities to snugs or ears cast on the cylinder flange; *e e* the piston-rod cross-head; *f f* the connecting-rod; *g* the crank; *h h* the crank-shaft, supported by the pedestals *i i*; *j* the eccentric, for working the valve-rod *k k*; *l* the steam or valve chest; *m m* the fly-wheel; *n n* the driving-belt pulley; *o* the eccentric, and *p* the eccentric rod, for working the pump *q* which supplies the boiler; *r r r* the governor.

2086. As an example of portable engines movable from place to place, we give, in Plate XXXVIII., figures of the well-known engine manufactured by Messrs Tuxford and Sons, agricultural engineers, Boston. In fig. 1 is given a longitudinal section, in fig. 2 an end elevation, in fig. 3 a front elevation, and in fig. 4 a transverse section.

2087. *a*, figs. 1 and 4, the furnace; *b* longitudinal flue, with water-space *b′ b′* dividing same, and thus constituting, as it were, two flues; *c* take-up from flues to the tubes or smoke-box; *d d* tubes; *e* smoke-box leading into the chimney; *f f* chimney, with a perforated dome *g*, capable of being elevated by the rod *h*, which is made to slide up or down by the finger-buckles *i*, fig. 3; *j* joint to chimney, by which the upper portion is made to fall backward when travelling; *k k* steam-pipe; *l l* steam-regulator, for admitting or cutting off the supply of steam along the steam-pipe *m m*; *n* the throttle-valve, which is acted upon by the governor *x*, fig. 3, through the medium of a rod which passes through the hollow governor-spindle; *o* the steam-chest, to which a passage conducts from the throttle-valve *n*, within the foundation-plate, on which the chest and cylinder stand; *p* the cylinder of engine; *q* the cross-head to which the piston is attached: side-straps connect this lower cross-head with an upper one, which works up and down in guides in the steeple *y*; from this upper cross-head descends the connecting-rod which is connected with the crank: *r*, fig. 3, the force-pump, which has its plunger connected with the cross-head *q*; a water passage leads from the pump through the foundation-plate, and an upright pipe afterwards connects with the water-regulator *s*, fig. 1, which passes the water into a small chamber or water-door *t*: against this water-door the fire strikes after passing through the flues, and before it is returned through the tubes *d d*; the door, therefore, acts the part of a water-heating apparatus, whilst, at the same time, it prevents the engine-house from becoming unnecessarily hot: *u u* the exhaust-pipe, passing from the engine-house along and within the boiler, and turning up into the chimney; *v* the safety-valve, with a Salter's pressure-gauge *w*; *x*, fig. 3, the governors; *y* the steeple, with guides for connecting-rod; *z z* the fly-wheel, used also as a driving-pulley; *z′ z′* a pulley for driving any machinery from, which does not require so high a velocity as that driven from the fly-wheel; *a*, fig 2, *a′* fig. 1, a door to the smoke-box *e*: this door is readily opened, and admits of the tubes being easily brushed out, the soot and ashes being forced into the take-up *c*, fig. 1, where they are consumed, or are raked out through the flues *b* into the furnace *a*: *c'*, fig. 1, the furnace-door; *c*, fig. 4, water-space dividing the flue into two parts *b b*; *d d*, fig. 2, common water gauge-cocks; *e* glass water-gauge.

2088. The chief features of Tuxford & Sons' patent portable steam-engines may be summed up as follows—viz.: 1st, A vertical cylinder, with steeple arrangement of engine, the upper cross-head working in guides, capable of adjustment, for keeping them perfectly true, the engine being placed in an iron house, and under lock and key. 2d, The boiler, combining the advantages of both the flue and tubular boiler, and, whilst retaining the economy and portability of the tubular boiler, is released from the serious drawback against the tubular boiler —viz., the great tendency of becoming leaky at the tube-plates where the tubes join them. This great defect is partly accounted for from the circumstance of the tubes being of much lighter material than the other portions of the boiler; and when the furnace-door is opened for throwing on fuel, a rush of cold air enters, and, passing along the tubes, has on them a more sensible effect than on the other and stronger portions of the boiler, and hence a greater contraction; whilst on the closing of the door a succeeding expansion takes place, and these alternating influences speedily cause the leakage so generally complained of, with the great expense of frequent renewal of the tubes. Tuxford's boiler is stated to remedy this defect, from the circumstance of the flues through which the fire first passes being of the strongest substance of the boiler. There being a greater amount of resident heat in the thick substance of the flues than in the thinner substance of the tubes, the flues are not so sensibly affected upon the opening of the door for feeding the fire; and the air which enters, becoming heated as it passes along, when it reaches the tubes, enters them at a very different temperature than is the case with the ordinary tubular boiler. 3d, A safety spark-trap to the chimney, by means of the perforated dome.

Fig. 817.

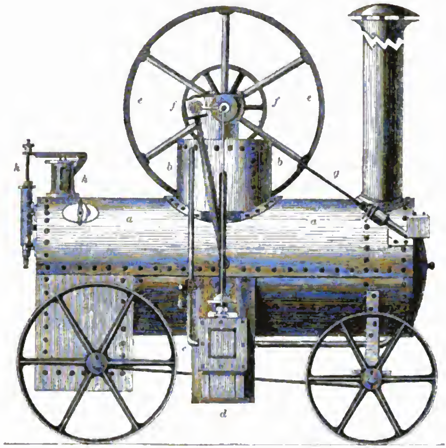


END ELEVATION (AT SMOKE-BOX END) OF TUXFORD'S PORTABLE ENGINE, IN PERSPECTIVE.

2089. In fig. 817 we give a perspective view of the smoke-box end of this engine. Although the plan of having the working parts under cover is possessed of many advantages, it is but right to state that the high temperature of the air with which they are surrounded adds to the cost and to the difficulty of maintaining efficient lubrication.

2090. *Haywood's Portable Engine.*—In fig. 818 we give an elevation of a very compact form of portable engine of 2½-horse power, manufactured by Mr James Haywood, jun., of Phœnix Foundry, Derby. From its small size it can be easily transferred from place to place. It is of sufficient power to work chaff-cutters, turnip-pulpers, and thrashing-machines for small farms. The boiler answers the purpose of a steaming apparatus for the preparation of food for cattle. In the illustration *a a* is the boiler, *b b* the steam

Fig. 818.



SIDE ELEVATION OF HAYWOOD'S PORTABLE ENGINE.

dome or separator; *c* the steam-pipe leading to cylinder *d*; *e e*, fly-wheel; *f f*, pulley for driving-belt; *g* eccentric rod for working pump to supply boiler with water; *h h*, the spring safety-valve.

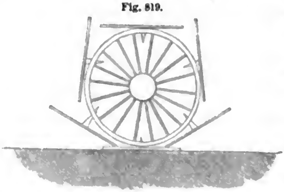
2091. In Plate IX. we give in fig. 1 a side elevation, and in fig. 2 a plan of a portable steam-engine, manufactured by Messrs Ransome and Sims of Ipswich. In fig. 1, *p p* is the cylinder; *q q*, *r r*, *s s*, *t t*, *u* the reversing gear hereafter described; *v v* fly-wheel or chimney; *x* smoke-box; *y y* steam-dome; *z* lever of spring safety-valve; 1, spring balance of safety-valve; 2, plate opposite fire-door; 3 3, hind wheels; 4 4, front wheels.

2092. *Boydell's Endless Railway for the Conveyance of Portable Engines from place to place.*—The present seems to be the most fitting place to notice a recent invention, now attracting the attention of agricultural machinists. We allude to the principal feature of the traction-engine of Mr Boydell, known as the "endless railway;" this being mechanism applicable to wheels of carts or portable locomotive engines, to enable them to go over the softest ground, and overcome obstacles which would, under ordinary circumstances, be difficult to be overcome, if not insuperable, and, by greatly facilitating the draught, economises steam and horse power to a considerable extent.

2093. The original patent was taken out in 1846, and was for apparatus which "consisted in the application of movable detached parts of a railway to the wheels of carriages, whereby each part is successively placed by its wheel on the road or land over which the carriage travelled, each part of the portable railway when down allowing its wheel to roll over it, the wheel depositing and lifting the parts of the railway in succession." In 1854 a second patent was taken out for improvements, consisting "in the application of side pieces to each portion of the movable rails, so as to obtain a more extended bearing for the rails whilst the wheel is passing over them; and for the construction of parts of the portable rails, by combining tough iron and wood to obtain great strength with lightness."

2094. In fig. 819 we give an illustration of the arrangement of a wheel with the parts of the endless railway attached; fig. 820 being a view of one of the separate parts of which this is constructed; and fig. 821 that of one of the double guides fixed to the side of the wheel, by which these parts are lifted from and deposited on the ground in succession. The parts of the rails, fig. 819, on which the wheels run are affixed to a plate, of which the surface is considerably wider than that of the tire of the wheel. By this arrangement a broad bearing surface is afforded, preventing the sinking of the wheels into the soil. The ends of the bearing-plates match into each other, and extend beyond the portion of the rail fixed to them. This is done so that when the wheel arrives at one end of a portion of the rail, a portion of the bearing-rail is still left over, and the wheel is received on to and supported by the portion of the rail on the succeeding bearing-plate, before it leaves the bearing-plate of the previous part.

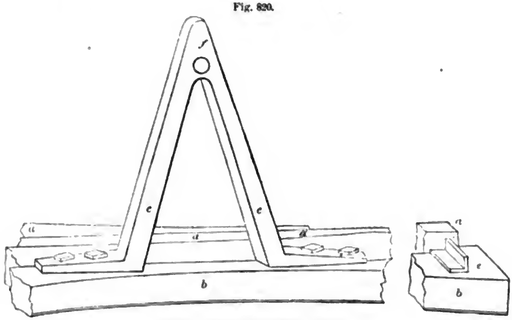
Fig. 819.



BOYDELL'S ENDLESS RAILWAY.

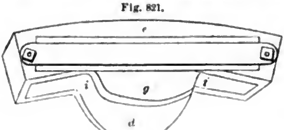
2095. In fig. 820 each portion of the rail *a a a* is fixed to the bearing-plate *b*, to which a triangle *c c* is affixed; this passes between the guide-plates *d e*, fig. 821, affixed to the side of the wheel, a pair being given to each bearing-plate. A stud or pin *f*, fig. 820, is attached to the triangle, and the guide-plates have raised pieces *g*, fig. 821, with hollows or notches *i*. Stops, *e*, fig. 820, are also provided, one on one end of the bearing-plate, the others projecting from the side of the wheel in certain positions, six of these projecting stops being applied to it. There are thus twelve stops—one to each of the six bearing-plates, and six to the wheel. The studs *f* and stops *e* are necessary

Fig. 820.



DETAIL OF RAIL OF ENDLESS RAILWAY.

Fig. 821.



DOUBLE GUIDE FOR ENDLESS RAILWAY.

to lay the bearing-plates correctly on the ground, in manner following: On the wheel revolving, the stud *f*, fig. 820, of the bearing-plate enters the farthest notch *i*, fig. 821, in the guide-plate, whilst the projecting stop of the wheel takes into the stop *e*, fig. 820, in the bearing-plate. Similar stops may be applied in the opposite position to assist in backing the wheel, and the bearing-plates will be taken up or lifted correctly by the studs *f* coming into the back notch of the guide-plates *d e*, fig. 821, the other end of the bearing-plates coming into contact with the stops. By these arrangements the parts of a portable railway will at all times be laid down and taken up correctly, notwithstanding the bearing-plates are detached, and independent of each other.

2096. The invention has been applied in numerous instances to ordinary carts and waggons, and by the authorities at the War Office, for the dragging of heavy guns over yielding surfaces: for this latter purpose it has been very successful. It is also becoming largely applied to portable steam-engines, enabling them to do much of the carting operations of the farm. It is but justice to the inventor, whose untiring efforts are worthy of all praise, to state that we have repeatedly seen a portable steam-engine to which the "endless railway" was attached, go over ground and obstacles with ease which would have brought an engine with ordinary wheels to a complete stand-still.

2097. *Direct-acting Engines.*—The expense attendant upon the variety of moving-parts in the ordinary beam-engine, as the examples in Plates XXXIV. and XXXV., in order to convert the rectilinear motion of the piston into the circular one of the fly-wheel, renders it a difficult matter to produce it very cheaply; the class of engines, therefore, known as the "direct-acting," have come much into use, especially where low powers are required. In direct-acting engines, the aim is to transmit the power of the piston-rod as directly as possible to the crank-shaft. This is done very generally by attaching a cross-head to the piston-rod, as *e e*, fig. 1, Plate XXXVII., causing this to slide between guides *d d*; the connection between the cross-head and the crank *g* being effected by the connecting-rod *f*. All the forms of high-pressure engines we have given, with one or two exceptions, are of this class of direct-acting engines.

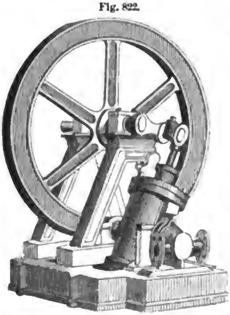
2098. A very obvious disadvantage possessed by this form is the friction caused by the working of the cross-head between the guides, and the exact parallel movement being prevented by the cross-pull caused by the throw of the crank. To prevent the friction as much as possible, care should be taken to have the form of the working surfaces calculated to work together with as little friction as practicable. Where it can be used, brass should form one of the working surfaces, iron and brass working together with less friction than iron and iron; the working surfaces should be flat, and parallel to one another. In one form of portable agricultural engine we noticed a very objectionable form of piston-guide. The cross-head was in the form of what may be called the *tenon* of a "dovetail joint;" the surface on which it moved being a long bar, the shape of which was such as to pass into the angular dovetail opening of the cross-head, after the manner of a mortise. The intention here was obviously to save material and workmanship, by having the cross-head and guide as compact as possible; but from the peculiar form and comparatively large extent of the rubbing surfaces, a very considerable amount of friction was induced.

2099. The second disadvantage of the form of direct-acting engines now under consideration—namely, the thrust and pull in the piston-rod by the throw of the crank—is much lessened by increasing the length of the connecting-rod. This is generally effected by making the frame higher, as in fig. 1, Plate XXXVII. Some engines have a connecting-rod as long as four times the stroke; a usual length is 2 feet of length for a 10 or 11 inch stroke.

2100. *Steam-Engines with Movable Cylinder and Piston.*—The second class of steam-engines are those which have movable cylinders and pistons, one example of which, applicable to agriculture, is given in an oscillating engine.

2101. *Oscillating Engines.*—The second class of direct-acting engines is that known as the "oscillating engine." In this form the cylinder is not fixed, but vibrates or oscillates on centres, these centres, or "trunnions," as they are termed, forming the supply and exhaust steam-pipes. As the piston-rod stuffing-box of the cylinder moves in the arc of a circle, the reciprocating motion of the piston-rod adapts itself to the various positions of the revolving crank; thus a connecting-rod is dispensed with, and the piston-rod attached to the crank-pin at once. There is a large variety of engines of this class introduced into practice; in some the trunnions are placed in the centre of the length of the cylinder, in some at the bottom, and in some the cylinder is inverted, the trunnions being at the upper end. The slide-valve in this form of engine is generally worked by means of a curved link attached to the eccentric rod, the link being guided vertically; the slot of the link is furnished with a small brass block, which slides backwards and forwards in it; the pin of the valve-lever passes through a hole in the block. The operation of the curved link is such as prevents the valve from being affected by the oscillation of the cylinder. In some forms of oscillating engines for agricultural purposes the valve-gearing is dispensed with; and the oscillations of the cylinder from side to side serve to admit the steam alternately to top and bottom of cylinder. Of this form—almost incapable of disarrangement—is one manufactured by Messrs Hick of Bolton, a figure of which we give in fig. 822. In this the slide-valve and eccentric movement are dispensed with, and a three-way cock adapted to the trunnion, this being opened and shut by the movement of the cylinder.

Fig. 822.



HICK'S OSCILLATING ENGINE

2102. An able authority considers this form as the best rotative engine. The objections raised against it, as to the wearing of the cylinder and stuffing-boxes to an oval shape, and the leaking and heating of the trunnions, have little foundation in fact: the wearing is found to exist—if it exist at all—in less degree than in ordinary engines; and so far from the trunnions heating, it may safely be said that no form of bearing is less liable to do so than this, inasmuch as the temperature is kept equal to that of the steam which flows through them. To prevent leakage of the trunnions, an authority recommends the packing to be squeezed in a cylindrical mould before being introduced; he also recommends the packing of hemp; to have, in addition, a brass ring introduced to embrace the pipe, cut spirally, with an overlap piece to cover the cut, and packed behind with hemp.

2103. *Details of Working-Parts of Steam-Engines.*—Having described the different classes of steam-engines in use for agricultural purposes, we shall add a few illustrations of details, showing their construction and the method of fitting up. In Section Fifth on Machine Construction in Book First, page 88, we have illustrated several of the details, which we shall at present simply refer to. We may add that the details now to be given here, and those already given in the Fifth Section, have special reference to the crank steam-engine in Plate XXXIII.

2104. *Details of Cylinder.*—We shall take the details of the cylinder first.

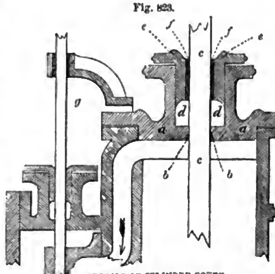
We have already described the form and working of the valves in pars. 2029 to 2035; we shall now illustrate a form of metallic piston.

2105. *Pistons.*—Pistons were formerly packed so as to work steam-tight in the cylinder, by having hemp rolled tightly round, and kept well lubricated. Now, however, this plan is discarded as clumsy and inefficient, and as involving a considerable loss of power through friction, and the form known as "metallic" is almost universally used.

2106. A very simple and efficient metallic piston is illustrated in figs. 1 to 10, Plate XXXIX. The piston is turned so as to leave a ledge *a a*, fig. 9, or a flat space all round. This space is filled up by two rings, the plan of one of which is shown at fig. 2, and the section at fig. 1. Small saw-cuts are made in the inside of the ring *b b*, fig. 2, and part cut out, as at *a*. This cut is made obliquely, not at right angles to the face of *b b*. Snugs are cast near *c*, the narrowest part of the ring, through which a bolt and nut is passed; by means of this the ends of *b b* are brought close together, compressing the saw-cuts, and bringing their edges together. The two rings are placed one above the other on *a a*, fig. 9, the narrow part of one being above the broad part of the other, and screwed up by the bolt *c*, fig. 2. The outer edges of the rings are ground so as to fit the interior of the cylinder very tightly. When placed inside the cylinder, the nuts *c c*, fig. 2, are loosened, and the rings allowed to expand: as the cylinder wears the rings expand, so as to keep the piston steam-tight. The piston-cover, fig. 5, is then passed over the piston-rod, and secured by the bolts *a a*, fig. 4, passing through the bolt-holes *b b*, fig. 9. The end of the piston-rod *b*, fig. 4, is fastened in the aperture *c*, fig. 9, by the key or cottar at *c*, fig. 4. The aperture is made to taper. Fig. 6 is a section of the cover in fig. 5; fig. 7 is a plan of the under side of cover; fig. 8 is a plan of under side of body, fig. 9; fig. 10 is a plan of top of body.

2107. *Piston-Rod.*—The piston-rod is kept tight in working up and down through the aperture in the cylinder cover, by the contrivance known as the "stuffing-box" or gland. This is shown in fig. 823, in the cylinder-cover *a a*; *b b* is the aperture through which the piston-rod *c c* works. This widens into a space *d d*; into this space a "gland" *e e* fits; the upper side of this gland is hollowed out, so as to form a kind of cup round the piston-rod, in which oil can be placed to lubricate it. The gland *e e* is of length sufficient to allow of a space *d d* being left, into which "hemp" or "patent" packing is put, closely enveloping the piston-rod. A brass bush, in which the piston-rod plays easily, is driven tightly in at *f f*. When the piston-rod begins to work loosely in the packing, and steam is allowed to pass through the stuffing-box to the atmosphere, the packing may be made tight by screwing down the gland by means of the bolts and nuts which secure it to the cover. When the packing becomes wider, it can be easily renewed by taking out the gland (by unfastening the nuts), and withdrawing the old packing from *d d*, and substituting new. The figure also shows the packing of the valve-rod *g*.

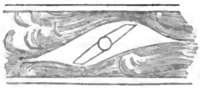
Fig. 823.



DETAILS OF CYLINDER COVER.

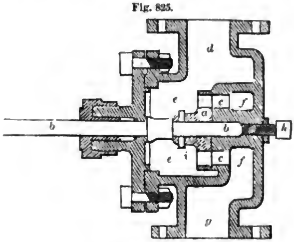
2108. *Throttle Valve.*—We now come to the methods in use by which the supply of steam to the cylinder is regulated. This is usually effected by a contrivance known as the "throttle valve." This is a flat disc, with its edge bevelled off, the central spindle working through the pipe in which the valve is placed. When the valve—by means of the lever fixed in the outer end of the spindle—is brought into the position in fig. 19, Plate XXXIX., the edges are brought in contact with the periphery of the pipe, and the passage is closed: by moving the valve out of this position *a*, the passage for the steam is made on either side of the valve. Fig. 18 is a cross section. By referring to fig. 824, the double contraction formed by the steam passing the valve is seen. In consequence of this obstruction of the steam passing to the cylinder, some engineers discard the use of this form of throttle-valve, and adopt the disc valve, an improved form of which is given in fig. 825. A circular disc or plate *a* is made to rotate by means of the stem *b b*, in close contact with another plate *c c*. In both these plates circular apertures are made, corresponding in size and position: when the valve *a* is moved, so that the apertures coincide with the apertures *c c*, full admission to the steam is given to pass through them; any movement of the valve *a*, however, from this position, closes in greater or less degree—in proportion to the amount of movement—the apertures in *c c*. Thus a very small movement of the valve *a* will give a considerable amount of opening for the admission of steam. In the form shown in fig. 825, *d* is the steam-pipe from boiler, where the apertures coincide as in the figure; the steam passes from the steam side of the valve *e e* to the supply side *f f*, and from thence to the cylinder by the pipe *g*. In this arrangement the valve is kept in an easy-moving position as regards the valve-seat by the set screw *h*, in conjunction with the collar *i*, on the stem *b b*.

Fig. 824.



CONTRACTION OF FLOW OF STEAM CAUSED BY THE THROTTLE-VALVE.

Fig. 825.



DISC THROTTLE-VALVE.

2109. *Steam-Engine Governor.*—We shall now describe the methods by which the admission of steam is regulated, and a uniformity of action secured. This is generally effected by means of the governor, by which advantage is taken of the centrifugal force, generated by the revolution of balls, to act upon the throttle-valve by a series of levers, the arrangement of which differs in many instances, but which is too well known to require description here. The defects of this form of "speed regulator" are principally these: first, the time consumed before the governor can act on the throttle-valve, by the levers taking a certain interval to attain their corresponding conditions; secondly, and principally, it is apt to attain the two extremes too rapidly—that is, it flies from the position of valve closed to valve opened without any nice degree of gradation. Thus, if an engine "runs" away, as it is termed, the balls fly so rapidly out that the valve is completely shut, and the engine brought up in such a manner as to induce a reactional movement, this oscillation frequently being continuous for some time. As in some processes, such as corn-grinding and thrashing, it is desirable to have a uniformity of action, many plans have been introduced by which to attain this desideratum.

2110. In Plate XXXIX., figs. 20 to 36 inclusive, we give details showing the construction of the governor in the crank engine in Plate XXXIII.; the whole drawn to a scale of $1\frac{1}{2}$ inch to the foot. Fig. 20 is a side view with section of ball, and fig. 21 an edge view of one of the levers *b' b'* and balls *c' c'* in Plate XXXIII. Fig. 22 is a sectional elevation of central spindle *d' d'* in Plate XXXIII. The snug *a a*, with double ends, is fixed on this. Fig. 23 shows a plan, and fig. 24 an end view of this snug or lug. The end *a* of the side-rods, figs. 20 and 21, passes between the ends *a a* of the snug, figs. 23 and 24; and are kept together by a pin passed through the holes made in each part. The spindle, fig. 22, is made hollow at one part of its length, to allow the rod *b b* to play up and down. This rod is connected with the lower snug *c c*, by a cottar or key passing through a slit *a a*, fig. 25, made on opposite sides of the central spindle, fig. 22; this cottar, as seen at *b*, fig. 25, passes through the snug *c c*—so that when the rod *b b*, fig. 22, moves up and down, it carries with it the snug *c c*, the slit in the central spindle allowing of the easy movement of the cottar *b*, fig. 25. In like manner the wharve or small pulley *d d*, fig. 22, corresponding to *g'* in Plate XXXIII., is connected with the rod *b b*, fig. 22. Fig. 30 is a plan of upper side of wharve or pulley, fig. 31 a section, and fig. 32 a side and edge view of the cottar. Fig. 26 is a plan of snug *c c*, fig. 22; fig. 27 an end view. Fig. 28 is a side and edge view of cottar. Fig. 29 is a side view of the lever *w* in Plate XXXIII.; fig. 33 a plan of the end of the lever which embraces the wharve *d d*, fig. 22. Fig. 34 *a* is a side and *b* an edge view of the stud *h'* in Plate XXXIII., on which the lever *w* vibrates; the part *a*, fig. 29, passes into the fork *a*, fig. 34, and is secured by the pin *a*, fig. 36, passing through the apertures shown in the figure; the washer *b*, fig. 36, is then put on the part *c*, and pin *d* driven through the washer and the end *c* of the pin *a*. Fig. 35 gives a side and edge view of the levers *e' e'*, Plate XXXIII.; the fork *a* embraces the part *b*, *b* of the side lever, figs. 20 and 21; the part *b*, fig. 35, passing between the ends *a a* of the snug, figs. 26 and 27. In figs. 157 and 158, Section Fifth, Book First, paragraph 383, we give a section and elevation and the description of the bearing in which the upper part of the central spindle *d' d'*, Plate XXXIII., revolves. In fig. 159 different views of the brasses or bushes for this bearing are given. In fig. 164, paragraph 387, are given views of the step in which the lower part of the central spindle *d' d'*, Plate XXXIII., revolves; this step is supported by the bracket *u*, bolted to the wall *a*, Plate XXXIII.

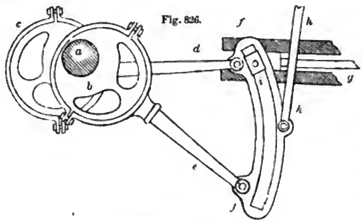
2111. The various parts of the pedestal or plummer-block, in which the shaft of the engine in Plate XXXIII. revolves, are shown in figs. 160, 161, 162, 163, and 164, in pars. 385, 386, and 387.

2112. In fig. 178, par. 407, we give various views of the crank *k*, Plate XXXIII., and of the butt of the lower end of the connecting-rod *g*, fig. 2, Plate XXXIII. In fig. 181, par. 409, are views of the eccentric *y*, fig. 2, Plate XXXIII., as also in fig. 183, par. 412. Of the piston cross-head is fig. 198, and par. 425.

2113. *Reversing-gear.*—In many engines now in use, what is called "reversing-gear" is adopted. By this the engine can be immediately altered from the forward to the backward direction. This movement is especially useful in engines driving corn-mills, thrashing-machines, hoisting gear, &c., as the direction in which the fly-wheel and driving-pulley are going can be instantly changed. This is effected by what is known as the "link motion."

2114. This movement is explained in fig. 826. The crank shaft is at *a*; two eccentrics *b* and *c* are fastened on the shaft; one to give the forward motion, the other the backward, to the slide-valve. The eyes of the rods *d e* of these are attached by movable joints to the ends of a curved link *f f*, the radius of which is equal to that of a circle described by the eccentric rods revolving round their centres. Let *g* be the slide-valve rod, connected at one end to a brass bush *i*, sliding between the sides of the grooved link *f f*. The link is capable of being raised or depressed by the lever *h h*, actuated by appropriately arranged levers attached to a pin, this pin being placed in the centre of the link,—this being the point of least vibration. In the position as in the figure, the valve-rod *g* is evidently under the influence of the eccentric *c d*. Suppose this is the "forward" one,—to give the engine the "backward" movement, all that is necessary to be done is to lift the link upwards by the lever *h h*, so as to place the bush *i* opposite the end of the eccentric rod *b e*. The end of the link with the eccentric rod *c d* will then be as much above the bush *i* of the valve-rod as the eccentric *b e* is below it in the figure. When the link is in such a position as to place the bush *i* of the valve-rod exactly in the middle of the link, the valve will then have no motion at all. The action of each eccentric rod being equal and counteracting, the link will vibrate in the centre bush; the ends describing curves, the centre of which is the bush of the valve-rod *i*. In fig. 1, Plate IX., the reversing gear is shown at *q q*, *r r*, *s s*, *t t*, and *w*; *r r*, *s s* the forward and backward eccentric rods; *q q* the lever corresponding to the rod *h h*, fig. 826; this is worked by the handle *t t*, vibrating on the stud *u*. As the outer extremity of the handle *t* is raised or depressed, the curved link is raised or lowered by the lever *q q*, and the forward eccentric or backward set in operation accordingly.

Fig. 826.



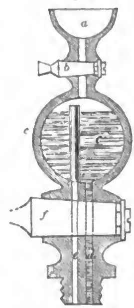
REVERSING GEAR OR LINK MOTION

2115. *Force-Pump.*—In figs. 11 to 17, Plate XXXIX., we give the "force-pump" of the engine in Plate XXXIII., to supply water to the boiler: *a*, fig. 11, the pump-plunger; this is carefully turned, and works tight through the stuffing-box *b b*, as the plunger is not usually made to work tight in the body of the pump. The formation of the vacuum depends chiefly on the tightness of the stuffing-box; this, therefore, should be always kept in good repair, and the cover screwed tightly down to keep the glands close up with the packing; *c* is the suction and *d* the delivery valve, access being gained to them by the caps or covers *e* and *f*. These covers should be put down with packing, to be as tight as possible. The delivery-pipe leading to the boiler is attached to the flange, shown by the dotted circles at *d*, and at *c*, fig. 12, which is a plan of the pump. As much of the efficiency of the pump depends on the condition of the valves, they should be examined from time to time through the covers *e* and *f*. The valve is shown in section in fig. 13, the under face at fig. 16, the valve-seat in fig. 14, and plan of the upper part of the valve in fig. 15. *a*, fig. 13, is the conical part, which fits into a corresponding conical surface *a a*, fig. 14, in the valve-seat. The closer the connection between the conical surfaces of the valve and seat, the tighter will the valve be. If they are found after wear not to be tight, they may be made so by rubbing them together by turning the valve round repeatedly in its seat, with oil and emery between them.

2116. In fig. 17, Plate XXXIX., we give the method of connecting-eccentric rod with pump-plunger. The plunger *a a g*, *h h g*, fig. 11, is provided with a circular eye *g*; the lower end of the eccentric rod is made as at *b* and *c*, fig. 17; the edge of the plunger-eye *g*, fig. 11, being passed between the sides *b* of the eccentric-rod end, fig. 17. A pin is then passed through the eyes of the rod and the plunger, and kept in its place by a key passing through a slot made in the end of the pin.

2117. *Piston Lubricator.*—In the ordinary forms of agricultural engines, the journals and bearing surfaces are kept well enough supplied with oil by means of the oil-holes generally provided; all that is necessary being a look-out so as to keep them well supplied, and prevent over-heating — a fruitful source of loss of power. To lubricate pistons and other parts under steam pressure, on the ordinary plan, the engine has to be stopped. To keep up the supply without stopping the engine, is a desideratum effected by the ingenious invention of Morton's Lubricator, a section of which we give in fig. 827.

Fig. 827.



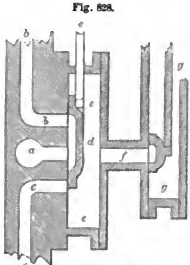
PISTON-LUBRICATOR.

2118. "It consists of an oil-cup *a* at the top, with a neck below, through which is a vertical passage for oil to a globular vessel *c* beneath it; a stop-cock *b* being placed in the neck, by which the vertical passage may be opened or closed. The lower portion of the globular vessel is connected with a stand which is furnished with a shouldered screw at its lower end, by which it may be attached to the part requiring to be lubricated. This stand is also furnished with a stop-cock *f*, and has two vertical passages *d* and *e* within it; one, *d*, passing from the bottom of the globular vessel *c* to the point where lubrication is required, the other, *e*, being continued upwards by a tube through the globular vessel nearly to its upper end, so as to be above the surface ot the lubricating liquid. In the stand is a second stop-cock *f*, with two passages through it corresponding with the two passages *d* and *e*, by which means they are both opened or closed by the turning of the stop-cock.

2119. "When a fresh supply of oil is required at the point of lubrication, the stop-cock *b* must be closed, and *f* opened, by which means the steam or other pressure passing through the passage *e* is made to act on the upper surface of the oil, with the same force as that with which it acts on its lower surface through the passage *d*. The pressure on both sides of the lubricating fluid being thus equalised, it is at liberty to flow downwards by its own specific gravity, thus obviating the inconvenience attending the ordinary oil-cup of requiring the machinery to be stopped for the purpose of lubrication. When the machinery is not at work, and lubrication therefore not required, the stop-cock *f* must be closed and *b* must be opened. It is particularly applicable to the pistons of high-pressure engines."

2120. *Expansive Working.*—We shall now consider the subject of working steam-engines expansively. By this is meant an adjustment of the valves, by which the steam is prevented entering the cylinder during a portion of the travel of the piston; the remainder of the stroke being completed by the steam expanding and filling the remaining portion of the cylinder. If the steam were admitted during the whole of the stroke, the motion of the piston would become so greatly accelerated, that at its termination the shock resulting would tend materially to damage the machine. To prevent this in the earlier forms of engines, it is conjectured that means were taken, such as shutting the injection-cock or the steam-valves, before the completion of the stroke—and hence, as supposed by good authority, arose the knowledge of the value of the method of working expansively. The following is Mr Bourne's clear statement of the advantages of this method of working engines: "It accomplishes an important saving of steam, or, what is the same thing, of fuel; but it diminishes the power of the engine while increasing the power of the steam. A larger engine will be required to do the same work, but the work will be done with a smaller consumption of fuel. If, for example, the steam be shut off when only half the stroke is completed, there will only half the quantity of steam be used. But there will be more than half the power exerted; for although the pressure of steam decreases after the supply entering from the boiler is shut off, yet it imparts during its expansion *some* power; and that power, it is clear, is obtained without any expenditure of steam or fuel whatever."* If the steam is cut off at *half* stroke, the performance of the engine is multiplied 1.7 times; if at *one-third* stroke, 2.1 times; at *one-fourth*, 2.4 times; at *one-fifth*, 2.6 times; at *one-sixth*, 2.8; *one-seventh*, 3; *one-eighth*, 3.2 times. The degree of expansion depends also in some measure upon the tightness of the packing; hence the necessity of keeping the piston-rod packing and the piston itself in good repair.

Fig. 828.



EXPANSION-VALVE.

2121. *Expansion Gearing.*— There are numerous forms of "expansion gearing" in use, but we do not consider it necessary to describe any of these, save the very simplest. One of these methods we illustrate in fig. 828. Let *a* be the port leading to the atmosphere or "exhaust port;" *b* the "upper-port" steam-passage; *c* the "lower-port" steam-passage; *d* the valve in the steam-chest *e e*, to which the steam is supplied through the port *f*. This port is capable of being opened or closed by means of a supplementary slide-valve *g*, working in a valve-case supplied with steam from the boiler. It is evident that any quantity of steam can be admitted to the main valve-casing *e e*, and consequently to the cylinder, by adjusting the time when the valve *g* shall cut off the communication between the valve-casing *e e* and *g*. This "cut off," as it is technically termed, is effected by altering the amount of play of the valve *g*, by varying the throw of the eccentric by which it is moved.

Fig. 829.

EXPANSION CUT-OFF.

2122. One method by which the throw of the eccentric is altered is shown in fig. 829. Let *a a* be the crank-shaft, on which a plate or large boss *b b* is cast; in the face of this two holes are bored and "tapped;" two bolts *c c*

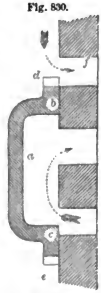
* BOURNE's *Catechism of the Steam-Engine*, p. 111, 4th edition. Longmans, London.

are worked in these, having square heads. In the eccentric *d d*, an aperture or slot *e* is made, having its circular ends of same diameter as crank-shaft *a*; this slot admits of the eccentric being moved up and down on the shaft *a*, so as to change the relative distance of their respective centres, and consequently the throw of the eccentric. To fix the eccentric at any desired point, the bolts *c c* are screwed hard up, so as to press against the face of the eccentric. The bolts slide in slots *f f*, to admit of the movement of the eccentric.

2123. *Lap of Steam-Valve.*—The method adopted most generally, especially in small engines for working expansively, is by giving what is technically termed "lap" to the ordinary slide-valve. This is effected by giving an extra length to the face of the valve, so as to cover the port sooner than would be the case if no lap existed. This lengthening of the valve face is made towards what is technically termed "the steam side" of the valve—that is, the outside of the valve towards the interior of the valve-casing: the side *b* of the valve towards the eduction port, fig. 830, is termed the "eduction side;" towards this there is generally little extension of the valve face or lap.

2124. The effect of this extension of valve face will be easily understood by an inspection of fig. 830. Suppose the ordinary valve without lap is that part *a b c*, shaded by cross lines; if the valve face is lengthened by parts shown by the white spaces at *d* and *e*, it is evident that the valve-port will be shut much sooner. Thus, suppose the valve to be commencing its upper stroke, the port *f* is shown completely open when the valve has no lap; but by the addition of lap, as at the part *d*, it is clear that the port will be so much the sooner closed as the part *d* is lengthened. The extent to which expansion by means of "lap" in the valve can be economically carried out, is about one-third of the stroke—that is, the port must be closed when the piston has performed two-thirds of its stroke.

Fig. 830.



LAP AND LEAD OF VALVE.

2125. *Lead of the Valve.*—As, from the peculiar motion of the eccentric, the valve opens but slowly during the first part of its travel, the steam passing to the eduction-port has some difficulty in escaping, and in proportion to this arises a certain impediment to the working of the engine from the piston having to be forced down, as it were, against the pressure of the steam which has a difficulty in passing from the cylinder. To obviate this, and to relieve the cylinder of the steam as instantaneously as possible after the completion of the stroke, what is termed "lead" is given to the valve. By this is meant the amount of opening of the valve when the piston has reached the termination of its stroke. Thus, when the piston begins its new stroke, the steam is escaping freely to the eduction port through the valve, and the resistance to the stroke of the piston is obviated or decreased. This lead of the valve is obtained by fixing the eccentric on the shaft, more or less out of the usual line of centres, according as required.

2126. *Estimation of Power of Engines.*—In estimating the working capabilities of a steam-engine various terms are in use. The "nominal power" "the actual or effective power," and the "duty" of an engine, are terms conveying different meanings, but which are frequently confounded. The *nominal*, or, as it is termed, the "horse-power" of an engine, conveys an exceedingly vague and unsatisfactory notion of the working capabilities of a steam-engine. It should be confined merely to imply the *size* of the engine. The rule given by Mr

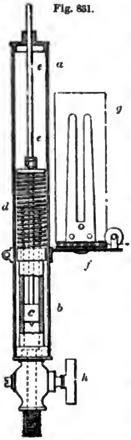
Bourne for estimating the nominal or horse-power of an engine is as follows: "Multiply the square of the diameter of the cylinder in inches by the cube root of the stroke in feet, and divide the product by 47—the quotient is the number of nominal horses' power of the engine."—(*Catechism of the Steam-Engine*, p. 46.) To save the trouble of making this calculation, we give the dimensions of cylinders of steam-engines (high pressure) from one to six nominal horses' power, under different pressures of steam per square inch. For this we are indebted to the very useful work, Templeton's *Workshop Companion*, containing a large number of rules useful in everyday practice (Weale, London, 5s.)

2127. Under a pressure of 25 lb. to the square inch, the diameter of cylinder of a one horse-power is $3\frac{3}{4}$ inches; of two, $5\frac{1}{4}$; of three, $6\frac{1}{2}$; of four, $7\frac{1}{2}$; of five, $8\frac{1}{4}$; and of six horse-power, 9 inches diameter. Under a pressure of 30 lb. to the square inch, a one-horse engine has a diameter of cylinder equal to $3\frac{1}{2}$ inches; a two, $4\frac{3}{4}$; a three, 6; a four, $6\frac{3}{4}$; a five, $7\frac{1}{2}$; and a six, $8\frac{1}{4}$ inches. Under a pressure of 40 lb. to the square inch, one horse-power is 3 inches; a two, $4\frac{1}{4}$; a three, 5; a four, 6; a five, $6\frac{1}{2}$; and a six, $7\frac{1}{4}$ inches. The working pressure for high-pressure engines should not exceed 45 lb. to the square inch.

2128. By the "effective" power of a steam-engine is meant the number of times 33,000 lb. the engine is capable of lifting one foot high per minute, this being decided upon by engineers generally as the unit of dynamical effect. To estimate the effective power of a steam-engine, the first essential requisite is a knowledge of the mean pressure in the cylinder during the stroke; this is gained by means of an instrument termed the "indicator."

2129. *Indicator.*—The construction of this is shown in fig. 831. It consists of a cylinder of brass *a b*, in which a small piston *c* works, nearly tight; a spring *d* is connected with the piston *c* and spindle *e e*; a bracket *f* supports a cylinder *g*, which is capable of being turned vertically on its axis by a cord passing round a pulley made on the periphery of its lower part. The cylinder is made to rotate on its axis by the cord passing to the cross-head of the piston: in a direct-acting engine — or the parallel motion of a beam-engine—on the return stroke of the engine the cord is relaxed, and a spring placed within the cylinder *g* brings it back to its original position. Thus the stroke of the engine causes the cylinder *g* to rotate part of its revolution in one direction, the spring acting to bring it back or make it rotate in the opposite direction. By this arrangement the alternate motion of the cylinder *g* is made to correspond to the reciprocations of the piston. A piece of paper is wrapped *once* round the cylinder *g*; a pencil is attached to a spring arm, connected with the spindle *e*; the paper wrapped round the cylinder *g* is kept in its place by upright spring-clamps; the point of the pencil is kept in contact with the surface of the paper by the spring arm. A scale is attached to the indicator vertically; the zero point of this is the point of the atmospheric line. The marks 1, 2, 3, *above* the zero point, show that when the diagram cuts the lines drawn parallel to the atmospheric line on a level with these points, the pressure is 16, 17 lb., &c.; when it cuts lines on a level with the marks 1, 2, 3, &c., *below* the zero point, the pressure is 14, 13 lb., &c. The zero point is the line of atmospheric pressure on 15 lb. The indicator, thus arranged, is screwed into an aperture in the cylinder cover; the steam, thus communicating with the

Fig. 831.



STEAM-ENGINE INDICATOR.

interior of the indicator, gives the same pressure on the piston *c* as on the piston of the cylinder. The cord passing round the pulley of cylinder *g* is attached to the piston cross-head. The result of the up-and-down motions of the pencil in contact with the paper, caused by the reciprocatory motion of the piston *c*, corresponding to the movement of the steam-engine piston, together with the circular motion of the cylinder *g*, caused by the tightening and relaxation of the cord attached to the piston cross-head, is the describing of a curved line on the paper more or less approaching to the form of a parallelogram. Previous to opening the cock *h*, a line, called the atmospheric or zero line, is described on the paper. This line is at the level of the pencil when it is uninfluenced by the steam-pressure. The line is drawn by causing the barrel to revolve. The cord, passing from the pulley to the cylinder *g*, to the moving part by which it is actuated, passes over pulleys, so as to reduce the motion, and thus renders the motion of the piston and that of the indicator proportional to one another.

2130. The diagram described shows the steam-pressure in the cylinder during the whole stroke. To ascertain the "mean pressure," the diagram obtained is divided into an equal number of parts in the direction of its length, lines being drawn through these at right angles to the atmospheric or zero line. Parallel to the zero line, and through the points corresponding to the points on the scale of the indicator, draw other lines. Next measure the distances from the points where the diagram line intersects the vertical lines to the atmospheric line; add all these distances together—their measurement being taken from a scale corresponding to that in the indicator—and divide them by the number of columns or spaces into which the diagram is divided, and the quotient is the mean effective pressure in the cylinder during a whole stroke.

2131. *Rule to find the Effective Power.*—The mean effective pressure in the cylinder being thus found or assumed, find now the diameter of cylinder in inches; square this, and multiply it by .7854; the result is the number of square inches in the piston. Multiply the number thus found by the mean pressure per square inch; next multiply this by the velocity of the piston in feet per minute; and finally, divide by 33,000; the quotient will be the effective horse-power of the engine. Before dividing by 33,000, deduct from the product 2½ lb. per square inch for friction. The velocity of the piston per minute is found by multiplying the number of revolutions per minute by the length of the stroke.

2132. *Advantages of the use of the Indicator.*—The only satisfactory way of obtaining a knowledge of the working capabilities of a steam-engine, is by taking correct diagrams by means of the indicator. To those of our readers desirous of becoming acquainted with the best methods of obtaining correct diagrams, we would recommend *The Indicator and Dynamometer*, by Messrs Main and Brown: London, G. Hebert (8s. 6d.); or the work on the same subject by Mr Hopkinson of Leeds (7s. 6d.), published by Weale. The authors of these works give the following clear statement of the two important ends obtained by the use of the indicator: "1st, It enables us to discover whether there are any defects in those parts of the machinery by which the steam is admitted to the piston: for instance, it indicates whether the slides are properly set or leaky; whether the steam-ports are large enough; and, consequently, whether a different arrangement of the working parts of the machinery would be advisable. In fact, in the hands of a skilful engineer, the indicator is as the stethoscope of the physician, revealing the secret workings of the inner system, and detecting minute derangements in the parts obscurely situated. 2d, It discovers at any instant of time, and under any given circumstances, where it may be desirable to apply it, what is the actual power of the engine." Such is the value placed on the indications of this instrument in the manufacturing districts, that manufacturers have engineers who call on them at stated intervals, to "indicate" the power of their engines, and thus ascertain whether they are performing their work well and cheaply.

2133. By the term *duty* is meant the quantity of work done by the consumption of a certain quantity of fuel, without reference to time. In a preceding par., 1962, the reader will find some notes on this point.

2134. The "mean effective pressure" of a steam-engine may, for ordinary purposes, be ascertained with sufficient accuracy without the use of the "indicator," by taking from the pressure in the boiler one-fourth of its amount from loss sustained by cooling and expansion, and also 2 lbs. for other deductions: thus, the mean effective pressure where the boiler pressure is 60 lbs. is 43 lbs., for $60 - \frac{1}{4}(15) = 45 - 2$ lbs. $= 43$.

2135. When the diameter of a cylinder with steam, worked at a pressure of 50 lbs. is given, an approximative estimate of its power may be obtained by dividing the diameter by 3, and squaring the product: thus, the power of an engine with a cylinder 6 inches diameter is four horse,—$\frac{6}{3} = 2 \times 2 = 4$.

2136. *Steam-Power for Agricultural Purposes.*—To a very valuable paper by Mr William Waller, read before the Institution of Mechanical Engineers, at Birmingham, July 30, 1856, on the application of steam-power to agricultural purposes, we are indebted for the following description of the method employed to test and calculate the power of agricultural engines by the judges of the Royal Agricultural Society of England:—

2137. "The various engines are entered, declared at a certain power, at which only they are to be tested. Thus, suppose an engine having a 5-feet pulley, entered as an 8-horse engine running at 120 revolutions per minute. Eight stone of coal, of 14 lb. to the stone, with a certain quantity of wood to light the fire, are given to the engineman, who has previously had the engine at work, and run the steam down to 20 lb. or 25 lb. per square inch pressure, as the case may be, and emptied and swept out the fire-box. The fire is then relighted, and the steam is got up to 48 lb. per square inch, at which pressure the engine must start. The dynamometer (shown in fig. 220, par. 521, Book First, page 142), is supposed to have a 3 feet 6 inches belt pulley, and a 4 feet 6 inches wheel, with a friction break on it; then the centre of the pin or pointer to which the scale is attached, being 2 feet $7\frac{1}{2}$ inches from the centre, equivalent to a circumference of 16.5 feet, it will require a weight of 93.33 lb. suspended from the pin to give the desired 8-horse power, according to the following expression:—

$$\frac{93.33 \text{ lb.} \times 16.5 \text{ ft. circumf.} \times 5 \text{ ft. pulley on engine} \times 120 \text{ revolutions per min.}}{3.5 \text{ ft. pulley on dynamometer}}$$

equal to 264,000 lb. raised 1 foot per minute.

$$\text{And } \frac{264{,}000}{33{,}000} = 8 \text{ HP} = \text{the horse-power of the work done.}$$

The engine being started with a belt connecting the fly-wheel to the belt-pulley, a man is placed at the adjusting-screw of the dynamometer to slacken or tighten the friction-blocks, so as to keep the weight exactly in balance with the friction, and the pointer in a line with the centre of the shaft, during the whole time of working the engine. The number of revolutions of the break-wheel is registered on a counter by means of an eccentric on the shaft of the dynamometer. It is the business of the engineman to get the greatest possible number of revolutions out of the engine; then the total number of revolutions of the break-wheel divided by $\frac{5 \times 120}{3.5}$ gives the number of *minutes of duty* the engine has done; that is, the number of minutes of time the engine would have taken, if it had made *exactly* 120 revolutions per minute during the entire time of running, $\frac{5 \times 120}{3.5}$ being the number of revolutions per minute of the back-wheel, corresponding to 120 revolutions per minute of the engine. The minutes of duty converted into hours and decimals, and divided into the 14 lb. of coal supplied per horse-power, give the duty performed in the quantity of coal consumed per horse-power per hour. Thus, at the Carlisle Exhibition, Messrs Tuxford's engine did duty 3 hours 47½ minutes, or 3.8 hours; this, with 14 lb. of coal per horse-power, gives 3.7 lb. of coal per horse-power per hour.

2138. "The following Table gives the weight in pounds, to be placed in the scale of the dynamometer (shown in fig. 220, par. 521), for each horse-power from 4 to 10 horse-power, at intervals of 10 revolutions from 110 to 150 revolutions per minute of the engine. The table is calculated by the following formula:—

$$\frac{HP \times 33{,}000 \times d}{c \times D \times n} = w$$

where w = the weight in lb. to be placed in the scale of the dynamometer, HP = the horse-power of the engine, d = the diameter in feet of the pulley on the dynamometer, c = the circumference in feet corresponding to the distance of the pointer carrying the weight from the centre of the break-wheel, D = the diameter in feet of the driving pulley of the engine, and n = the number of revolutions of the engine per minute:—

TABLE OF WEIGHTS FOR DYNAMOMETER.

Revolutions of engine per minute.	4 Horse Power.	5 Horse Power.	6 Horse Power.	7 Horse Power.	8 Horse Power.	9 Horse Power.	10 Horse Power.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
110	50·90	63.64	76.36	89.09	101.80	114.55	127.28
120	46.66	58.33	70.00	81.67	90.33	105.00	116.66
130	43.08	53.85	64.61	75.39	86.16	96.92	107.70
140	40.00	50.00	60.00	70.00	80.00	90.00	100.00
150	37.33	46.67	56.00	65.36	74.66	84.00	93.34"

2139. *Fixed and Portable Engines for Farm Purposes.*—In the department of agricultural mechanism there is no point more open to discussion than the comparative advantages of fixed and portable engines for farm purposes. It is impossible, within the limits of our pages, to enter fully into the discussion, and to give even an epitome of the arguments *pro* and *con* which have been brought forward by the advocates of either view of the question. As conveying nearly all that can be said on this point, we here append the opinions of two authorities well calculated to form a correct estimate. The first we give is that of the late eminent agriculturist, Mr Philip Pusey, published in his Report to the Jury of the Agricultural Department of the Great Exhibition of 1851:—

2140. "If a farm be a large one, and especially if, as is often the case, it be of an irregular shape, there is greater waste of labour for horses and men in bringing all the corn in the straw to one point, and in again carrying out the dung to a distance of perhaps two or three miles. It is therefore common, and should be general, to have a second outlying yard. This accommodation cannot be reconciled with a fixed engine.

2141. "If the farm be of a moderate size, it will hardly, and if small will certainly, not bear the expense of a fixed engine; there would be waste of capital in multiplying fixed engines for a few days in a year. It is more common, therefore, in some counties, for a man to invest a small capital in a movable engine, and earn his livelihood by letting it out to the farmer.

2142. "But there is a further advantage in these movable engines, little, I believe, if at all, known. Hitherto corn has been thrashed under cover in barns; but with these engines, and the improved thrashing-machines, we can thrash the rick in the open air as it stands. It will be said, How can you thrash out of doors on a wet day? The answer is simple. Neither can you move your ricks into your barn in a wet day; and so rapid is the work of the new thrashing-machines, that it takes no more time to thrash the corn than to move it. Open-air thrashing is also far pleasanter and healthier for the labourers, their lungs not being choked with dust, as under cover they are; and there is of course a saving of labour to the tenant not inconsiderable. But when these movable steam-engines have spread generally, there will arise an equally important saving to the landlord in buildings. Instead of three or more barns clustering round the homestead, one or other in constant want of repair, a single building will suffice for dressing corn and for chaff-cutting. The very barn-floors saved will be no insignificant item. Now that buildings are required for new purposes, we must, if we can, retrench where objects are obsolete. Open-air thrashing may appear visionary, but it is quite common with the new machinery; nor would any one perform the tedious manœuvre of setting horses and men to pull down a rick, place it in carts, and build it up again in the barn, who had once tried the simple plan of pitching the sheaves at once into the thrashing-machine."

2143. We give an opinion on the opposite side—that of Mr Andrews, the agricultural engineer, and author of Weale's shilling volumes on Agricultural Engineering, in volume second of which the opinion we quote is given. While admitting the convenience of thrashing in the field, and the comparative perfection to which the operation of thrashing has arrived by the aid of the improved portable engines and portable thrashing-machines:

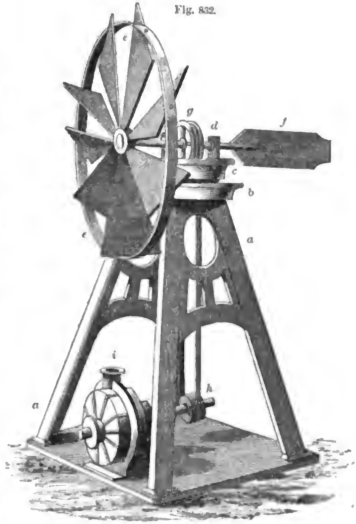
2144. "Nevertheless," he continues, "I do not myself think the system is so good as having the engine fixed, and the whole plant to form part of a regular plan. It is found in all manufacturing operations, that the more concentrated the machinery, and the more all the operations are got together, and under one general management, the better it is; and I cannot see why the manufacturing manner in which farm operations are now, and must every day still more become, should be an exception to the rule; but of this it is certain, that fixed machinery, permanently fitted up, will always do the work a great deal better and more economically than portable machines of any kind; that a fixed steam-engine and boiler of judicious design, will consume a much smaller amount of fuel, and last much longer, with scarcely any repair, than a portable engine, the repairs of which will be found enormous, as compared with a fixed engine, when extending over a number of years.

2145. "I am inclined to think that the preference is given to portable engines, chiefly because, from the want of properly-contrived homesteads, the work requiring to be done is distributed about, instead of being concentrated and brought under one roof; and often there are two or more small sets of buildings on the farm, instead of one general homestead."

2146. Section Fourth.—*Wind Power.*

2147. *Windmills as an Auxiliary Motive Power.*—Wind power for motive purposes, much used at one period, especially in districts where water-sources were not available, is being gradually superseded by steam power. Although maintained in operation at comparatively small expense, the power of wind is so variable in its action—so strong at times when not required, and so liable to fail altogether when most needed—that, in view of the advantages of steam, as a power easily managed, and perfectly to be depended on, we cannot recommend the farmer to erect a windmill. The only practically useful purpose to which a windmill can be applied is as an *auxiliary* power, in the manner carried out in numerous cases in the farming districts of the United States. In this way its utility is chiefly observable in pumping water from a low to a high elevation, as, for example, to a cistern placed at a level considerably above that of the farm buildings. A supply of water at pressure may thus be kept up, which can be distributed over the farm-buildings as required, or *employed to drive a small turbine* (par. 1938), the power of which may be made available for working straw-cutters, turnip-pulpers, &c. In fig. 832 we give a suggestive sketch of an auxiliary power of this kind, adapted to work a centrifugal pump. *a a* is the framing supporting a circular top *b* and cap *c*. The cap *c* carries two pedestals *d*, which afford bearings for the shaft of the wind-wheel *e e*. The shaft of the wheel *e e* carries a pulley *g*, which, by means of a belt, drives the pulley *h* of the centrifugal pump *i* (par. 1895). A useful diameter of wind-wheel, *e e*, will be 4 feet or 4 feet 6 inches. As the outward extremities of the sails move through a greater space and at a higher velocity than the minor extremities, the surfaces at these points should be flatter than at the other points. In the arrangement here shown as adapted to work a centrifugal pump, the wind-wheel *e e* remains always in the same position; for it is obvious that if the cap *c* revolved, being actuated by the vane *f*, which keeps the wind-wheel *e e* always up to the wind from whatever quarter it blows, the pulley *g*, on the shaft of the wind-wheel *e e*, would be hoisted round so as to be out of the plane of the pulley *h* on the shaft of the centrifugal pump *i*. To insure the arrange-

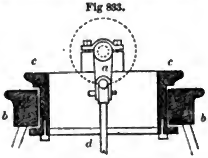
Fig. 832.



AUXILIARY WIND-POWER.

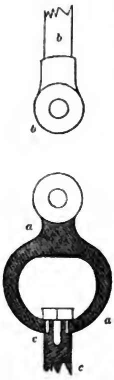
ment in working order, it is essential that the two pulleys *g* and *h* shall always be coincident. This can only be secured by the wind-wheel *e e* remaining always in the same position. To take advantage of the power of the wind from whatever quarter it blows, an ordinary pump must be employed. In this case the shaft of the wind-wheel *e e* is extended, and provided with a vane *f*, which keeps the wind-wheel always up to the wind. To insure this the cap *c c* is free to revolve on the top *b*, fig. 832, as shown in section in fig. 833. In place of the pulley *g*, fig. 832, a crank *a*, fig. 833, is employed, the connecting-rod *b* of which is continued downwards to the pump-plunger. The pump is placed immediately beneath the centre of crank. To enable the crank to take any position in accordance with the movement of the cap *c c*, and to prevent it hoisting or turning the rod which works the pump-plunger, the lower part of the connecting-rod *d* connecting the crank with pump-rod, should be provided with a "stirrup" or turn-joint *a a*, fig. 834. This will admit of the end of the connecting-rod *b b*, fig. 834, turning round without acting on the pump-rod *c c*, to which it is jointed.

Fig 833.



SECTION OF TOP AND CAP—SCALE, ¼ INCH TO THE FOOT.

Fig. 834.



STIRRUP-JOINT—SCALE, 3 INCHES TO THE FOOT.

2148. *Farm Windmills.*—Forty years ago, windmills, as a motive power to the thrashing-machine, were very commonly in use in many of the arable districts of Scotland, especially in the Lothians and the Border counties. With a handsome conical tower, surmounted by a cap resembling that of the huntsman, with five outspread arms inclining upwards to catch the passing breeze, and with a large wind-wheel—the governor or vane, projecting backwards, to act both as a counterpoise to the arms and a director against the current of the atmosphere, and the whole painted white—these windmills really formed picturesque and prominent objects in the landscape.

2149. The arms acted directly on a lying shaft, at the inner extremity of which was keyed a bevel-wheel which acted upon another at the upper extremity of the upright shaft, the lower end of which directly moved the thrashing machinery. The arms were turned to the wind by the governor on a segmental circular wheel of iron placed upon the top of the tower.

2150. These windmills have now gone out of use, because of the more easy and cheaper use of steam, and because in calm weather they could not be used, and their constant exposure to the weather subjected them to so much tear and wear, that, as a consequence, much cost was annually incurred in maintaining them in working order.

DIVISION FOURTH.—ARRANGEMENT OF MACHINES IN THE STEADING.

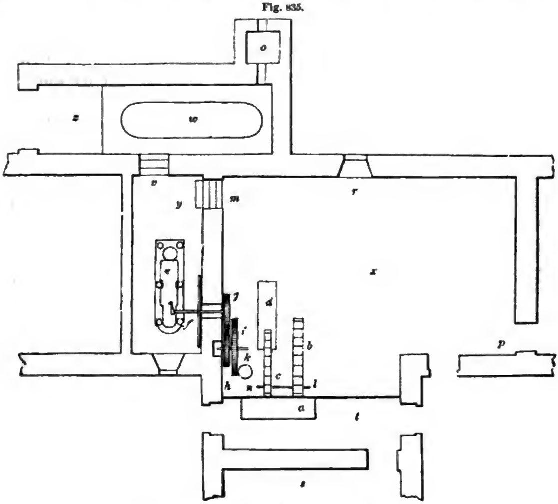
2151. Section First.—*Arrangement of Machines in the Ground-Floor of the Steading.*

2152. The introduction of a variety of machines for the preparation of grain for market, and of the food of stock, has necessitated, in improved farm constructions, special arrangements of premises by which to accommodate the machines required, and to facilitate the application to them of the moving power. We propose, therefore, in the present division, to give a few illustrations of arrangements which may be practically adopted.

2153. In figs. 835 and 836 are given plans showing the arrangement of machinery in the ground and upper floors of a barn adapted for the application of a Scotch thrashing-machine.

2154. A plan of the ground-floor of the corn-barn, with portions of the adjacent apartments, is shown in fig. 835: *x* is the corn-barn, *t* the chaff-house, *s* a part of the straw-barn, *y* the engine-house, *z* the boiler-house, *w* the boiler, and *o* the chimney. In this arrangement *a* is the position of the first fanners, *b* that of the elevator from the seconds-spout, and *c* that of the elevator from the

Fig. 835.



THE ARRANGEMENT OF THE GROUND-FLOOR OF THE BARNS.

clean-spout; *d* is a position for a second fanner, supplied by the elevator *c*. In the engine-house *y*, *e* is the position of the steam-engine, *f* the main-shaft, carrying the fly-wheel, and which is put in motion by the action of the engine upon the crank. The main-shaft carries also, in the usual construction, a spur-wheel *g*; but this member is subject to variation, according to the position of the engine-house and barns. In the present arrangement, and in many others, the spur-wheel *g*, as well as that marked *h*, act merely as intermedia, to bring the power into contact with the main spur-wheel *i*, this giving motion to the drum-pinion. The lasting advantage of having the straw-barn placed in the most central position to the whole steading, induces the one trifling addition of the intermediate wheels *g* and *h*, for the purpose of carrying the motive power from the main-shaft to the shaft of the great spur-wheel *i*; and this arises from the present arrangement, a practically-existing one, and chosen on purpose to show a difficulty, not admitting of the steam-engine being advanced so far towards the straw-barn that its main-shaft might lie nearly opposite to the drum of the thrashing-machine.

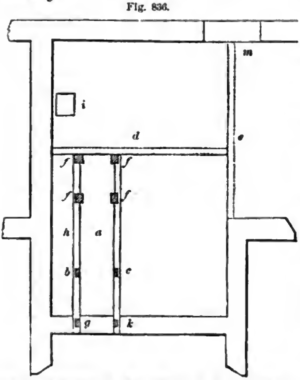
2155. In cases, again, where the corn and the straw-barns lie in one line of range—or even although their position may be at right angles, as here laid down, but their relation being such as to admit of the main-shaft coming nearly opposite to the drum—the intermediate wheels *g* and *h* become unnecessary, and the great spur-wheel *i* is then placed upon the main-shaft itself. It is of little importance which of these methods of taking up the power be adopted, the additional wheels adding but a small increase to the expense, and a little to the resistance; but the lasting advantages of the central position of the straw-barn *s* may do much more than balance these.

2156. Cases frequently occur, also, where only one intermediate wheel is required; and in others, it has been judged by some engineers more appropriate and expedient to dispense with all these wheels, and to substitute a large pulley in the place of the wheel *g*. In these cases, a pulley of proportionate dimensions is placed upon the drum-shaft, and the motion conveyed through a belt.

2157. The only subsidiary machine that is usually placed on this floor is the hummeller, at *k*; *n l* is the spindle on which the pulleys of the elevators *b* and *c* are keyed; *p* is the stair to the granary; *r* the window of the corn-barn; *m* the steps leading from the corn-barn to the engine-house *y*; and *v* is a door between the boiler and engine-houses.

2158. Section Second.—*Arrangement of Machines in the Upper Floor of the Steading.*

Fig. 836.



THE ARRANGEMENT OF THE UPPER-FLOOR OF THE BARNS.

2159. In the upper or thrashing barn, and in that appropriated to the corn in sheaf, the outline arrangement is represented in fig. 836, wherein the space *a*, formed by the placement of the foundation-beams *b* and *c*, is the position occupied by the thrashing apparatus. The foundation-beams are in the present case framed into beams *d* and *e*, represented by the dotted lines; the space *a* varies in length, according to the circumstance of the arrangement of the machinery, from 12 to 16 feet, and in width, according to the power by which the machine is intended to be worked, from 3 feet to 4 feet; *f f f f* mark the places of the posts which form the framework of the machine; *i* is a trap-door to form a direct communication between the upper and lower barns when desired; *g g* is the opening in the wall through which the straw falls from the shaker of the thrashing-machine into the straw-barn *k*.

2160. SECTION THIRD.—*Arrangement of Small Machines with the Moving Power in the Steading.*

2161. In Plate XL. we give illustrations of the arrangement of machines in a farm-steading, the property of the Right Hon. Sir W. G. Hayter, M.P., Southill Park, Bracknell, Surrey. The whole of the machines were manufactured by Messrs Garrett & Son, Saxmundham, Suffolk. Fig. 1 is the ground-plan; fig. 2, a section; and fig. 3, the chamber plan.

2162. In fig. 1, Plate XL., *a* is the boiler-room, *b* the boiler, *c* the vertical engine, *d d* the corn-barn, *e e* the thrashing, winnowing, riddling, and straw-shaking machine; *f f* the clean chaff store, *g g* the large straw-barn, *h* the chaff-store, *i* the litter store, communicating with the straw-cutting machine-room above; *j* the root-washing-machine and room, *k* the gearing for stone grinding-mill; *l l* the ground-corn and meal room, with steps *m* leading to floor above; *n n* the saw-mill, *o o o* the traversing rails, and *p* the travelling-carriage for bringing wood up to the saw-mill *n n*.

2163. Fig. 3 is the upper chamber, where *a a* is the place for the unthrashed corn, *b* the feeding part of the thrashing-machine, *c* the thrashing and finishing machine, with spout from elevator to carry clean corn to the weighing-machine *d*; *e e e* the granary, in one side of which the corn-bins *f f f* are placed; *g* the stair leading down to the corn and meal room in the floor below; *h* the water-tank to supply the farm-buildings, *i* the feeding part of stone grinding-mill, *j* the straw-cutter; *k k* straw and hay room, open to the large straw-barn; *l* the cake-store.

2164. In fig. 2, *a* is the furnace and boiler, *b* the engine, *c c* the shafting, *d* the saw-mill, *e* the grinding-mill, *f* the water-tank, *g* the straw-cutter.

2165. In Plate XL. we also give, in fig. 4, a plan, showing the arrangement of the machinery adopted on the farm of Mr William Dray, of the firm of Messrs Dray, the agricultural engineers, of Swan Lane, London, at Farningham, near Dartford, Kent. The following is a reference to the various parts:—*a a* the engine bed, *b b* the engine, *c c* the boiler, *d d* the root-washing machine, *e e* the root-mincing or pulping machine, *f f* the turnip-cutter, *g g* the meal-mill, *h h* the flour-mill, *i i* the oilcake-breaker, *j* the bean-mill, *k k* the oat-bruiser, *l l* the straw-cutter, *m m* the litter-cutter, *n n* the combined thrashing-machine, *o o* the soft-water tank to supply boiler, *p p* the pump drawing water from a well 200 feet deep to the tank *q q*, which contains 3000 gallons, and *u u* is the steaming apparatus. The whole of these machines are worked by the engine *b b*, through the medium of the shafting *r*, supported on the brackets *s*, and furnished with the riggers or pulleys *t t t*.

2166. SECTION FOURTH.—*The Preservation of Implements and Machines in the Steading.*

2167. The farmer is often charged with neglecting his implements, by unnecessary exposure to the weather; and the charge is partially well-founded, although those who make it do not understand the cause of the apparent neglect. Implements are used both within and without doors; and those used without doors may be divided into such as are in use every season, and only occasionally each season. It is scarcely to be expected that implements very frequently used in operating upon the soil can be otherwise than constantly exposed to the weather. Fortunately, on the score of economy, the implements thus employed are of simple construction; and are therefore less affected by changes of the weather, as well as less costly when renewed, than those of more complicated construction, which are used for a short time at certain seasons.

2168. The implement most frequently in use is the *plough*, and, being the chief one for operating upon the soil, is constantly exposed in the field. When it was commonly made of wood, exposure caused its decay much sooner than now, when it is wholly constructed of iron. Of so much use is the plough, that, were one to be seen stowed away in the implement-house, the conclusion would instantly be drawn that it was an old and worn-out one, or so ill-constructed and useless that it had to be set aside.

2169. *Harrows*, being the implement most commonly in use next to the plough, are much in the field, and exposed to the weather; and though made entirely of wood, last a long time. Not being required in winter, they are then removed from the field, and placed in the implement-house. The tines are usually laid and made sharp once a-year, and winter is the most proper time, just before the commencement of the oat-seed in spring. Harrows and ploughs are seldom painted after being made; but the harrows should be cleaned and painted when set past.

2170. The *roller* being only occasionally in use, in pulverising the soil, and rolling the young grass and spring crops in spring, and in pulverising the soil in summer-fallow, it is replaced in its shed whenever its services are no longer wanted. It should always be set past in a state of complete repair, that disappointment may not ensue at the moment it is desired to employ it; and the woodwork should be painted occasionally.

2171. The small ploughs, such as the *ribbing* and *double mould-board plough*, being used chiefly in summer, are allowed to lie too long in the fields after their employment has ceased; and, if removed before winter sets in, are placed in the implement-house dirty and worn. When no longer required, they ought to be scraped clean of earth, and the irons laid, before being put aside in the implement-shed.

2172. There are few implements which receive less regard, when not in use, than the whole class of *scufflers* and *grubbers*, which get leave to remain at the sides of head-ridges, and corners of turnip and potato fields, perhaps the whole winter. Many of them being made entirely of iron, do not suffer much, it is true, of deterioration from weather; but being composed of many small parts—of tines, coulters, wedges, and screw-bolts—these suffer from exposure, and execute their work indifferently on becoming worn. Instead, therefore, of being permitted to lie disregarded in the fields, their worn parts should be immediately repaired, and themselves placed in the implement-shed.

2173. All the classes of the more delicately constructed machines, as the *grass-seed*, *drill-sowing* and *turnip-sowing machines*, are seldom allowed to remain longer in the field than when in use; but though removed from the field, they are too frequently allowed to remain unheeded in the neighbourhood of the steading for a considerable time. Some, having no better place to put them, take them to the stack-yard and cover them with straw. Instead of this treatment, they should be immediately repaired, taken to pieces and cleaned, the journals greased, and the separate parts stowed away in the implement-house.

2174. Of the class of small manual implements, as *turnip-hoes*, *spreading-graips*, *dung-hawks*, *hay-knives*, *scythes*, many of them, if not placed in the implement-house whenever not in use, will be lost. When scythes and hoes get worn, they should be thrown into the old-iron store, and their helves furnished with new ones.

2175. Of all implements, *carts*, perhaps, receive the worst treatment. Though much in use in the fields, they are never left there, it is true, and are brought to the steading, but too seldom are put under cover, and are exposed to every species of weather—whether to the shrinking power of the sun's rays in summer, or the rotting effects of the damps and rains of winter; and, considering that carts are constructed of many parts, the wonder is they last so long with the treatment they receive. Their axles are not unfrequently neglected of grease; and as to their bodies and wheels being washed, not a mop is used or a drop of water ever thrown upon them—and they only receive ablution from a shower of rain, or an occasional passage across the ford of a river. A hole in the bottom or sides gets leave to enlarge, and a wheel-ring is allowed to become loose, till some day it flies off altogether, to the risk of breaking down the felloes. When such a mishap occurs from home, it tells strongly against the farmer's attention to his duties.

2176. All the in-door implements, as the *thrashing-machine*, should be cleaned out thoroughly every time a different kind of corn is to be thrashed, otherwise the samples of grain will be rendered impure. The gudgeons are usually oiled every time the mill is in use. Whenever a thrashing-machine requires repair, it should receive it immediately, otherwise a serious and expensive fracture may ensue.

2177. *Holes* in *sacks* and in *barn* and *chaff-sheets* should be instantly repaired, by patching and darning; nor should a broken mesh in a riddle be overlooked, so as to render the trouble of clean-winnowing grain unavailing.

2178. *Implement-house.*—The fitting up of the implement-house, for the accommodation of the finer and smaller implements, should be so done as to keep the floor nearly unencumbered, and give free access to every particular implement required at a time. Wheels, loose shafts, and angular pieces of iron, are best suspended against a wall from iron nails. Articles of length, such as sowing-boxes, are best supported against a wall upon brackets. Small articles of iron and of other materials, are best kept upon shelves. Hand-hoes, weed-hooks, and suchlike, are best placed in framed stands. Scythes are best suspended from the balks, and, where there are no balks, from nails in the wall. The bodies of small ploughs, grubbers, scufflers, should be placed along the foot of the walls, and kept in their position with cords fastened to staples driven into the walls. If every implement were put into its own place at the end of its season, confusion would be avoided, and many more articles find accommodation in the implement-house, than when everything is put down anywhere, without regard to order. To maintain order in the arrangement of the implements in the implement-house requires firmness on the part of the farmer; but the enforcement of order carries this conviction with it, that it is easier to put a thing in its own place than anywhere else, inasmuch as the place allotted for it contains and retains it in the best state and position.

INDEX.

THE END.

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EAST LOTHIAN OR SMALL'S PLOUGH.

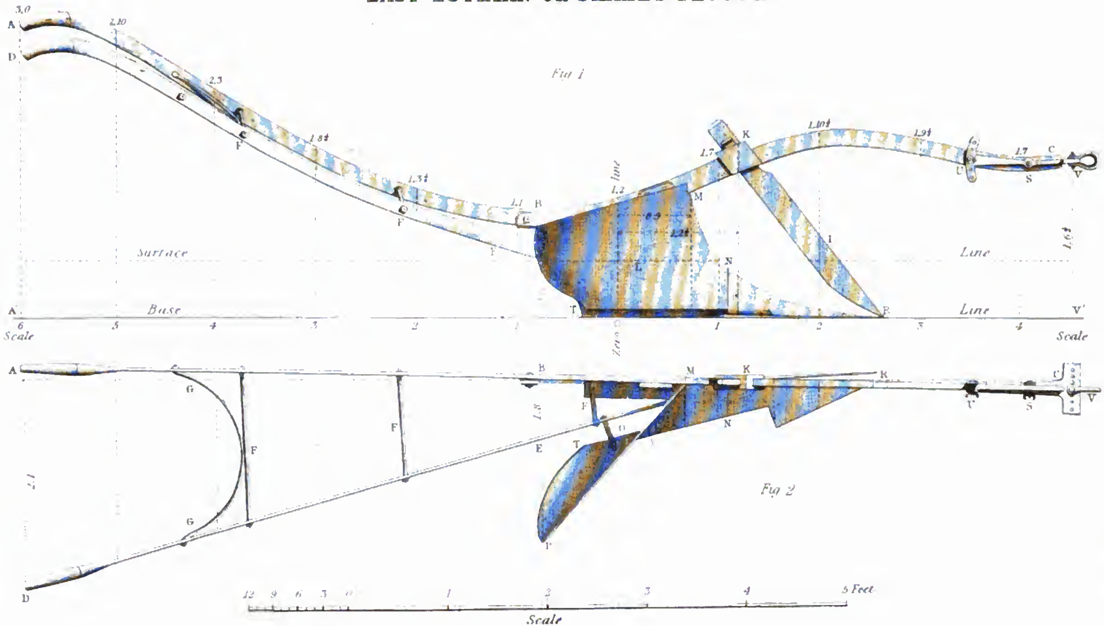
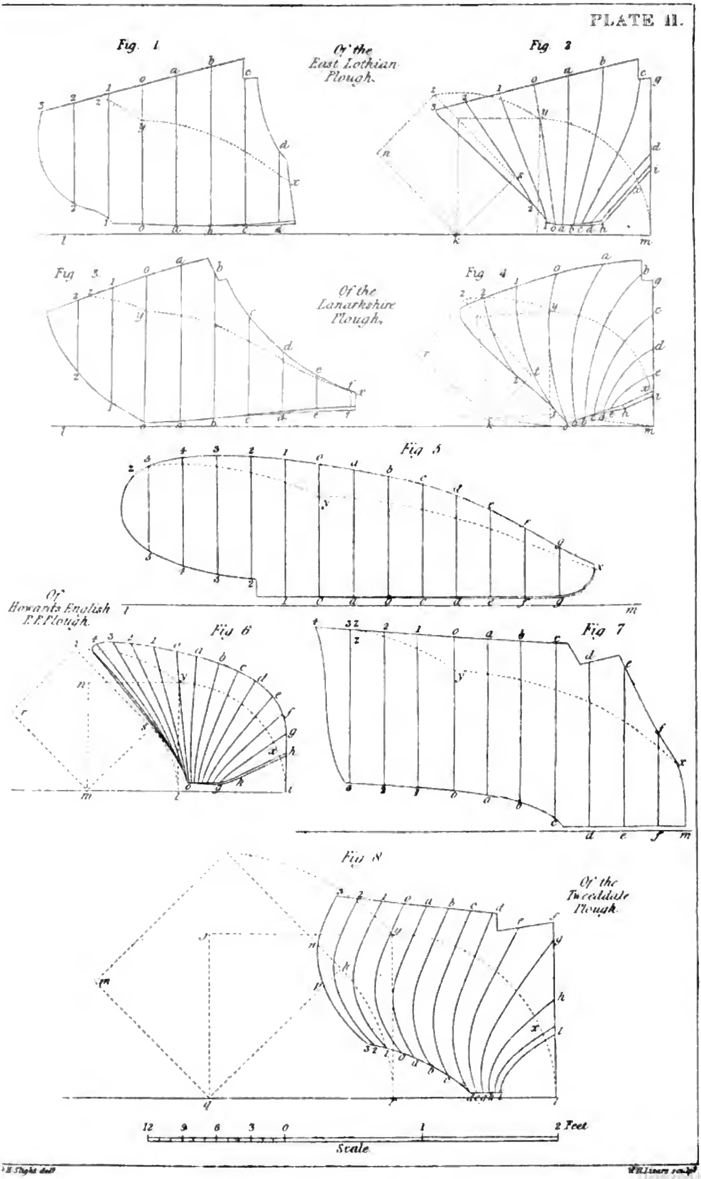


PLATE I

SECTIONS of MOULD-BOARDS.



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HOWARD'S PATENT P. P. PLOUGH.

PLATE III

Fig 1

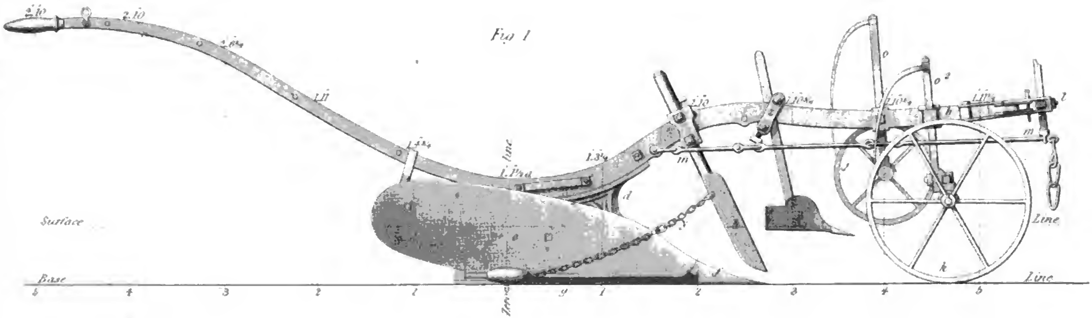
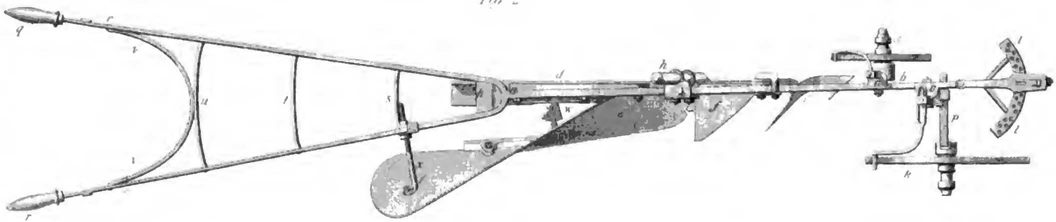


Fig 2



12 9 6 3 0 1 2 3 4 5 Feet

Scale

G. R. Sleight

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TWEEDDALE PLOUGH.

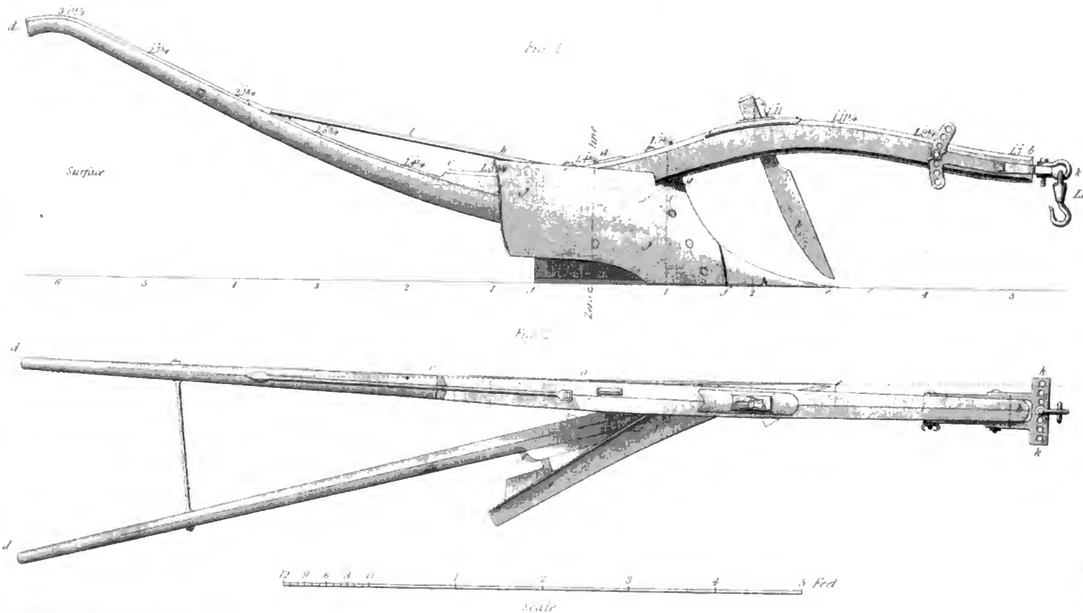

PLATE IV

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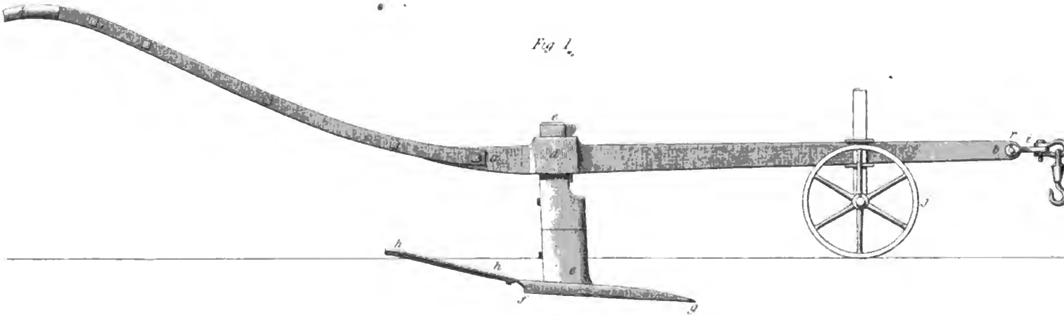
PLATE V

TWEEDDALE SUBSOIL PLOUGH.



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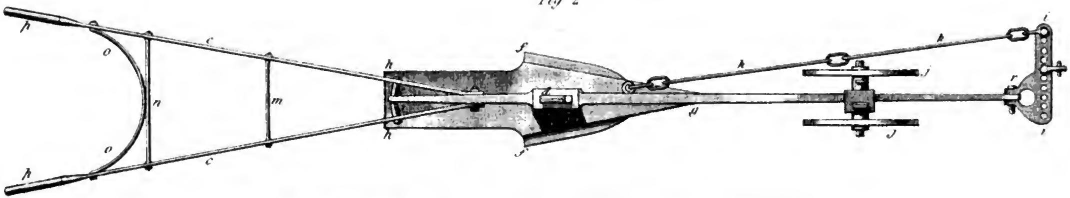

Fig 2.

Scale

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THE DRAUGHT OF THE PLOUGH.

Fig. 1

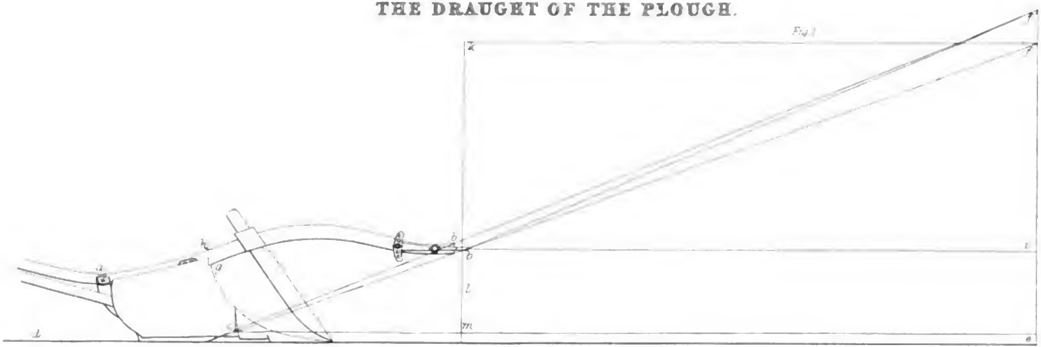

Fig. 2

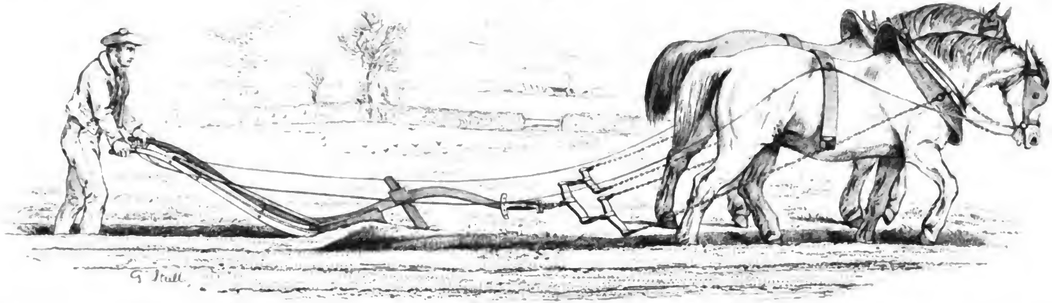

PLATE VI

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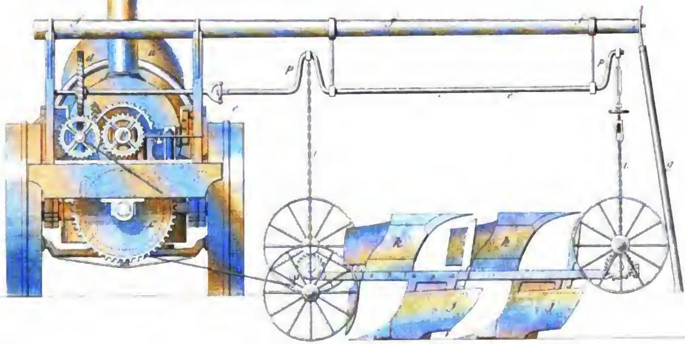
J. R. Scott, sculp.

TWEEDDALE STEAM PLOUGH.

Fig 1



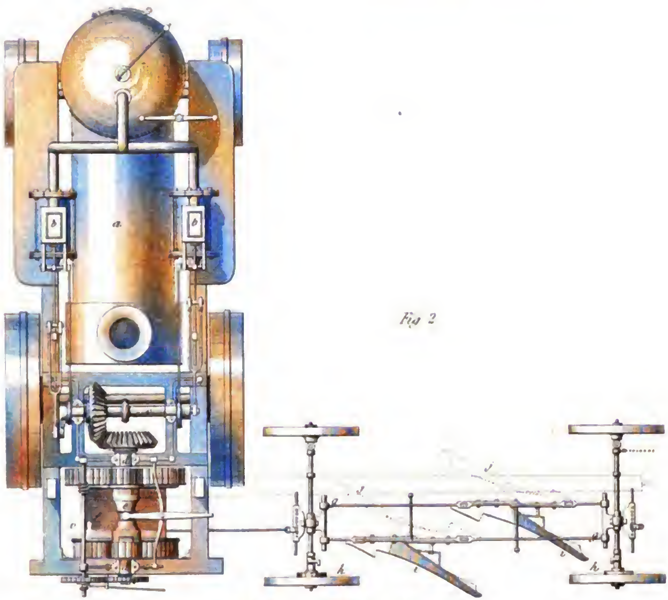


Fig 2

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G H Slight

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FOWLER'S STEAM PLOUGH.

PLATE VIII

Fig 1

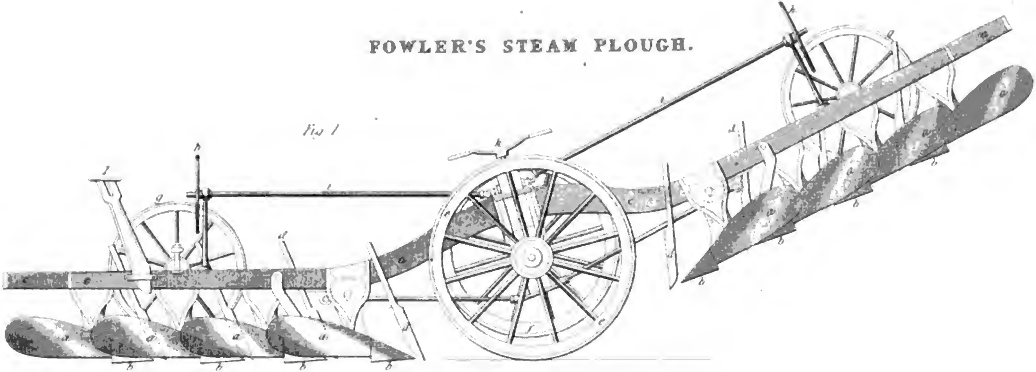
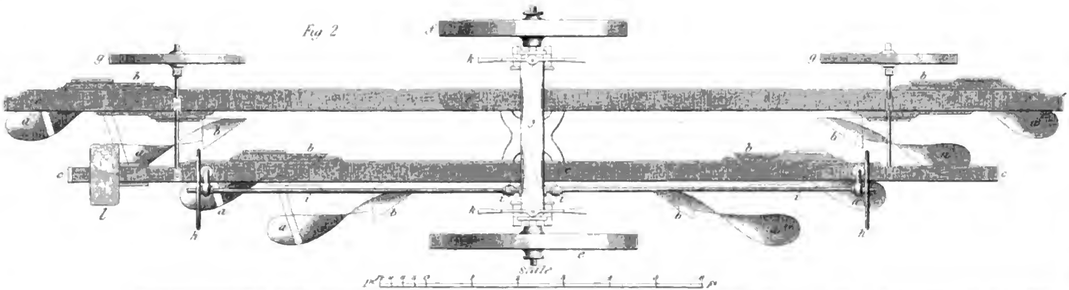


Fig 2



R. S. B. Delin.

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ENGINE AND WINDLASS FOR FOWLER'S STEAM PLOUGH.

Fig. 1

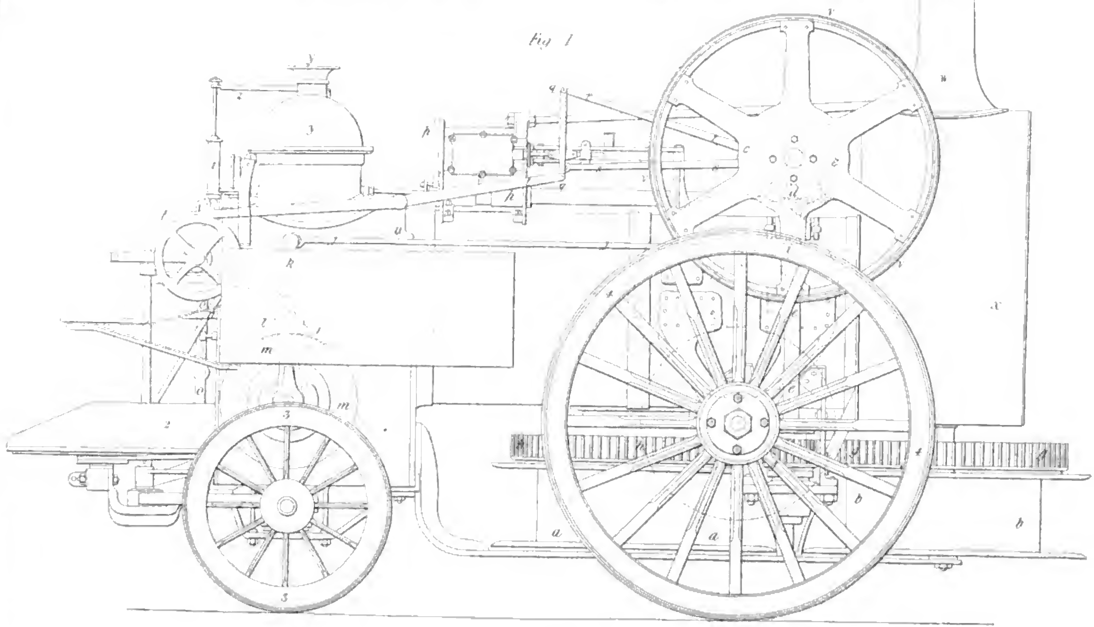

Fig. 2

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PLATE IX

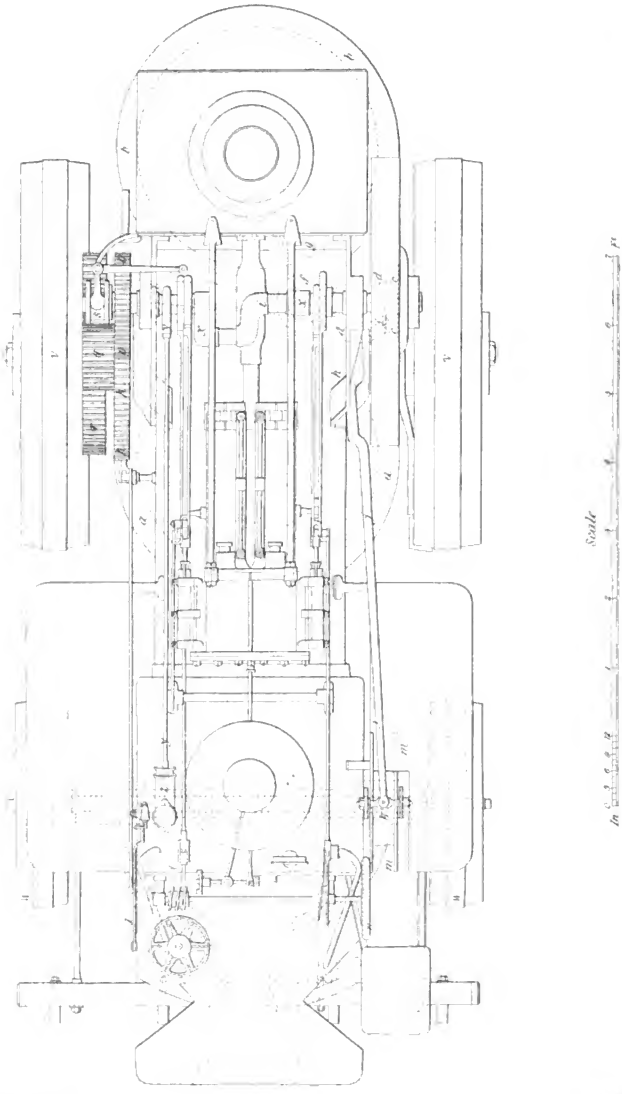

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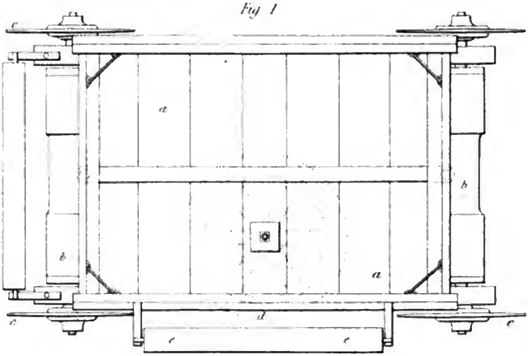
PLATE X

ANCHOR OF FOWLERS STEAM PLOUGH.

Fig 1



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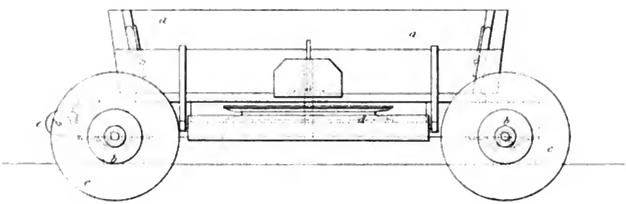
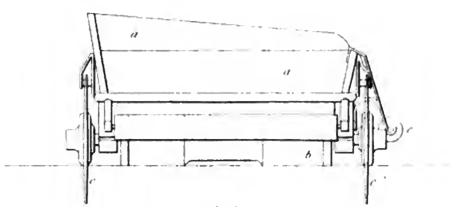


Fig 3



Scale

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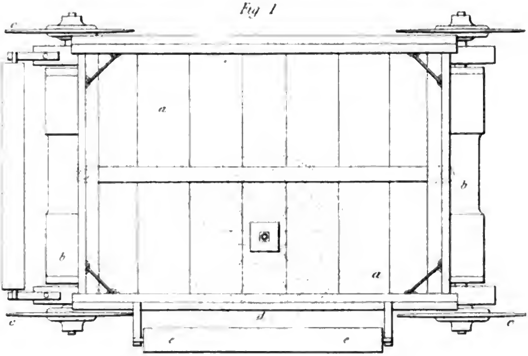
PLATE X

ANCHOR OF FOWLERS STEAM PLOUGH.

Fig 1



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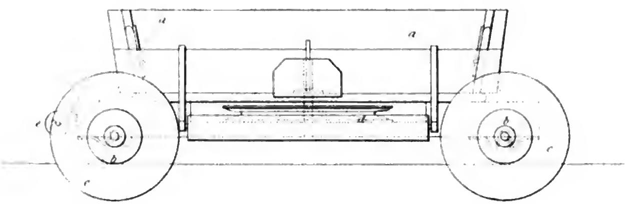

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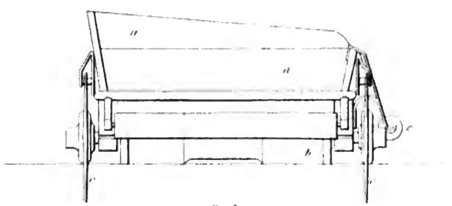

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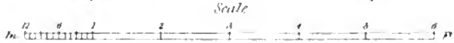

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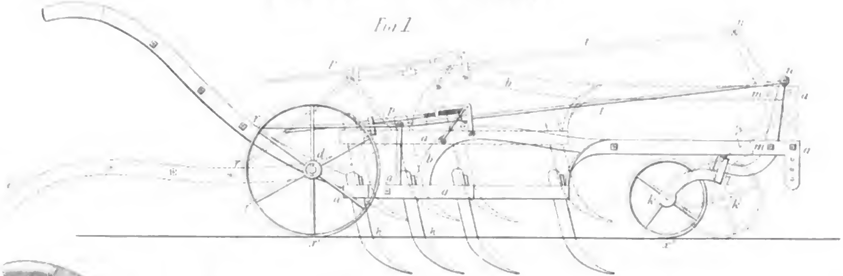
PLATE XI

KIRKWOOD'S GRUBBER.

Fig. 1



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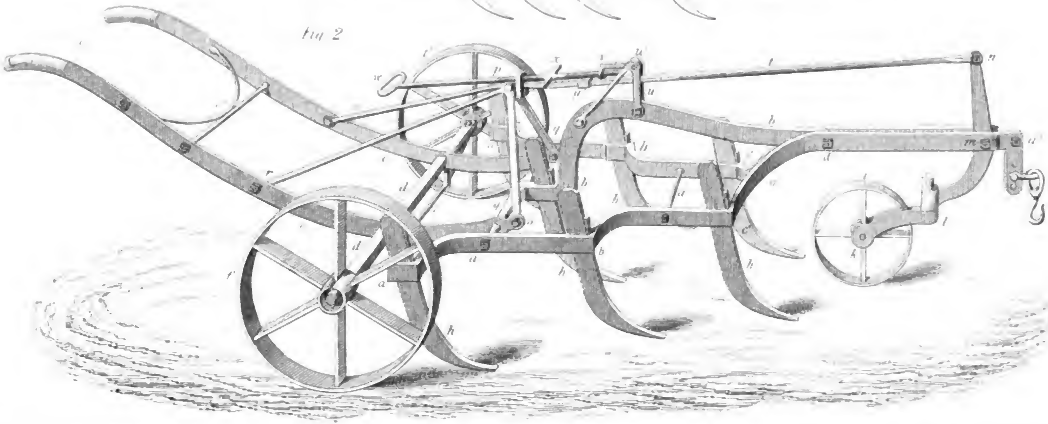

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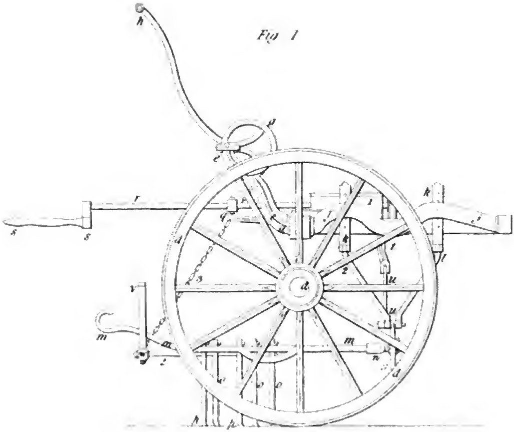
GARRETT'S HORSE HOE.

Fig. 1



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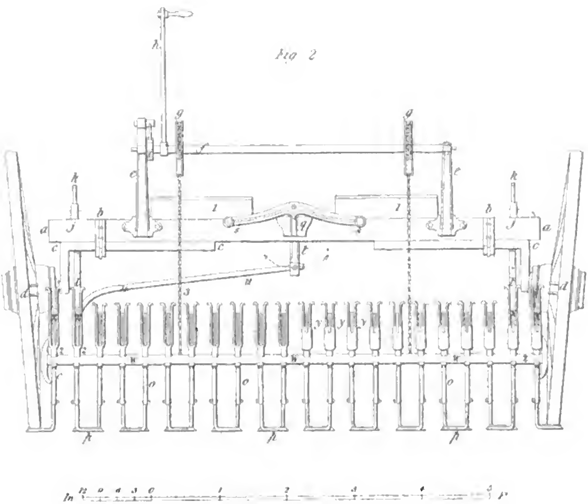

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ENGINE AND WINDLASS FOR FOWLER'S STEAM PLOUGH.

Fig. 1

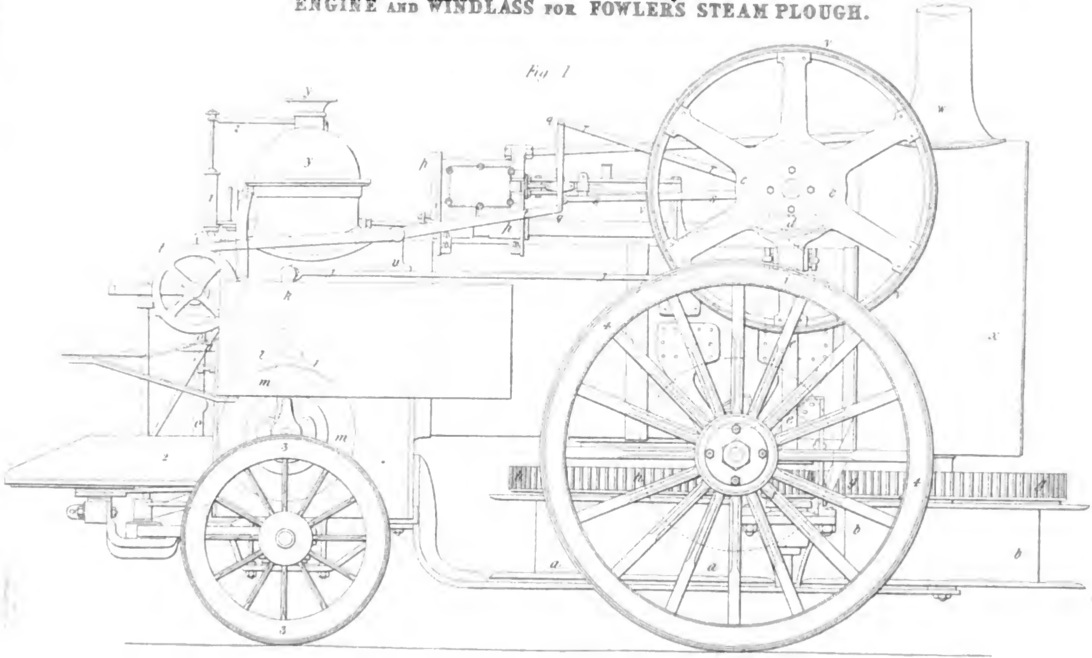

Fig. 2

N. S. B. Direx.

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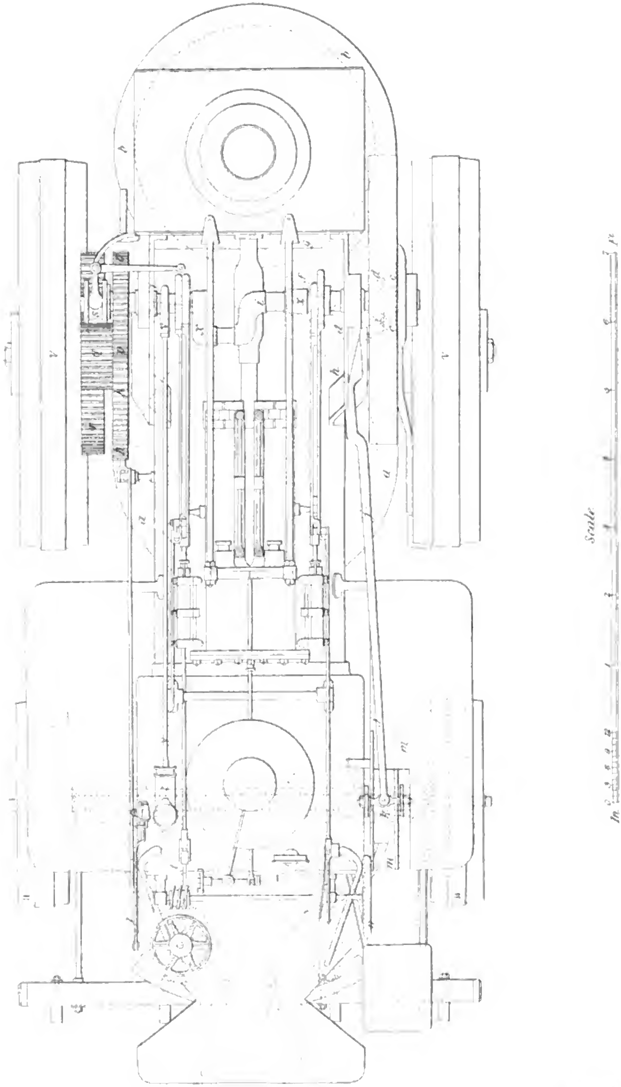

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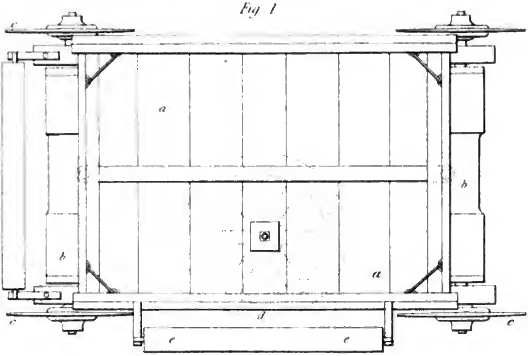
PLATE X

ANCHOR OF FOWLERS STEAM PLOUGH.

Fig 1



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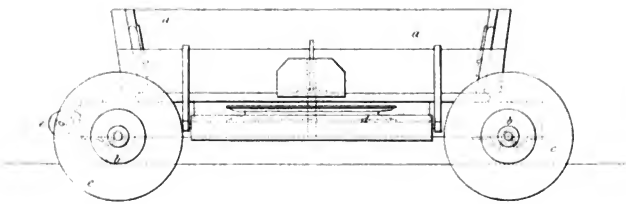

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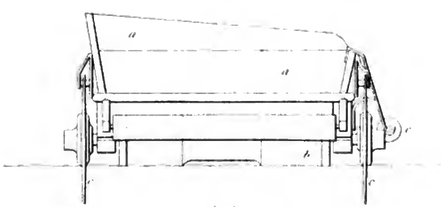

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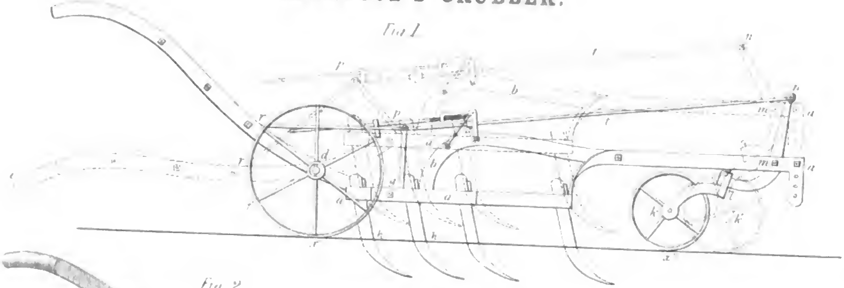
KIRKWOOD'S GRUBBER.

Fig. 1



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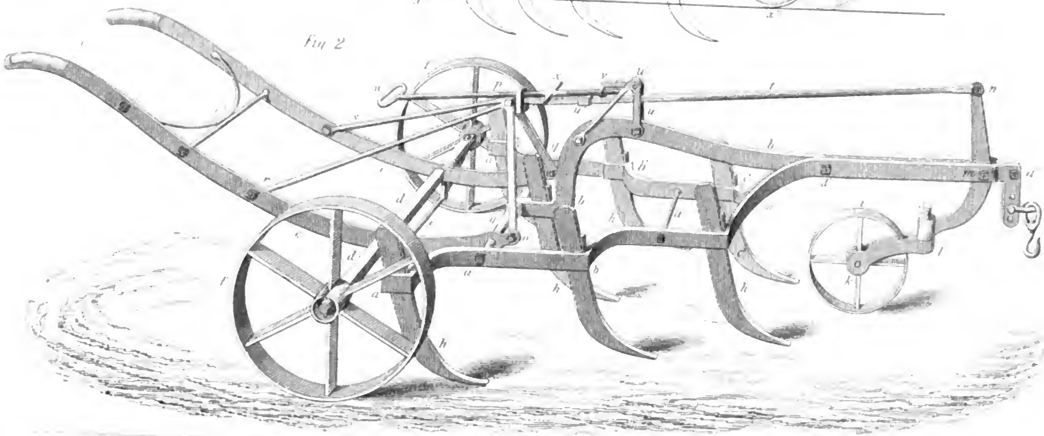

PLATE XI

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GARRETT'S HORSE HOE.

Fig. 1

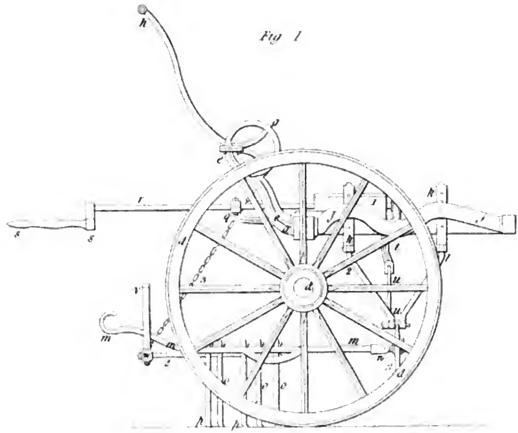
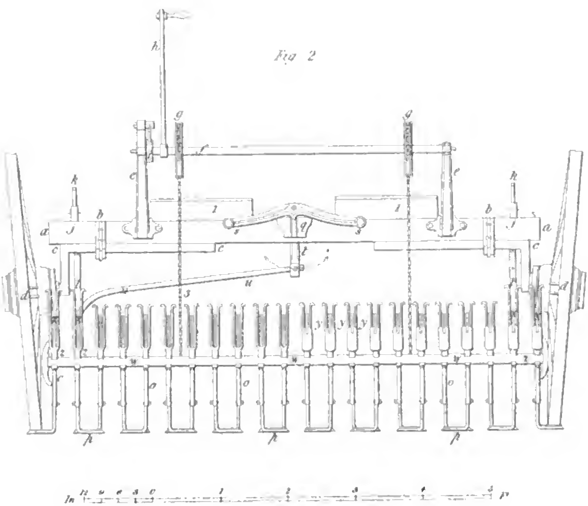


Fig. 2



S. B. Durex

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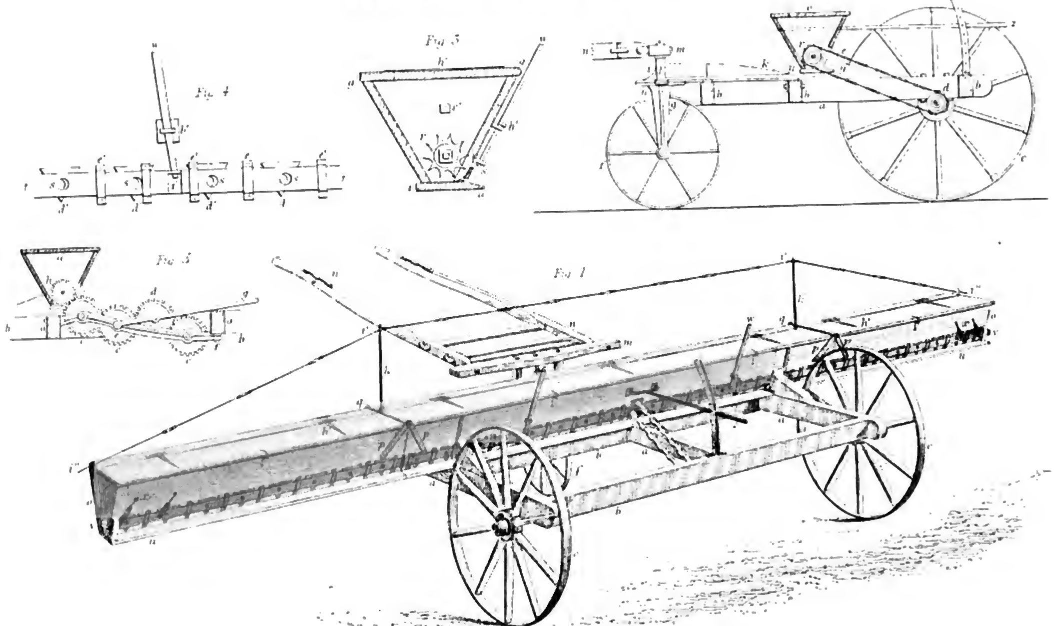
PLATE XIII

BROAD-CAST SOWING MACHINE.



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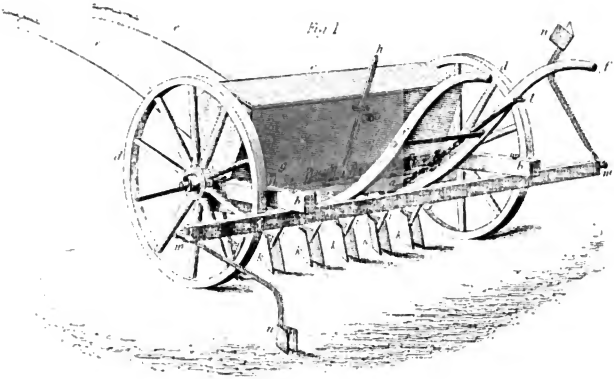
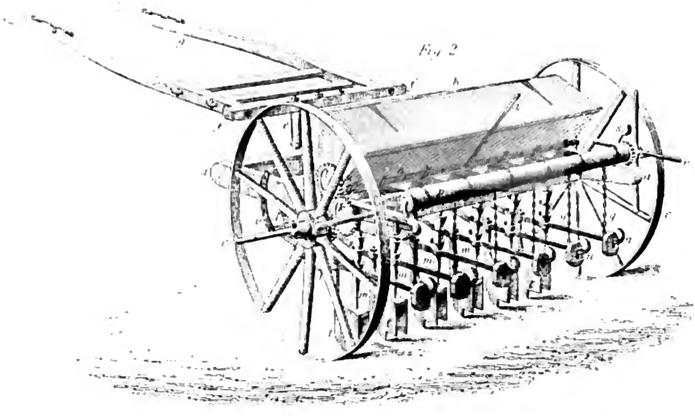
DRILL SOWING MACHINES.

Fig 1



The Common Drill Sowing Machine

Fig 2



The New Lever Drill Sowing Machine

J. R. Sayght Del.

W. H. Lizars Sculp.

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GARRETT'S LEVER CORN DRILL.

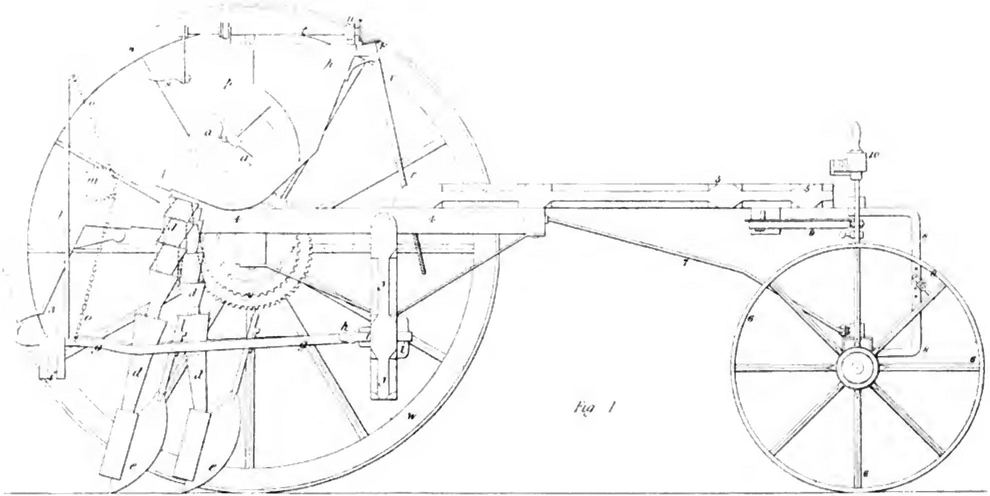


Fig. 1

PLATE XV.

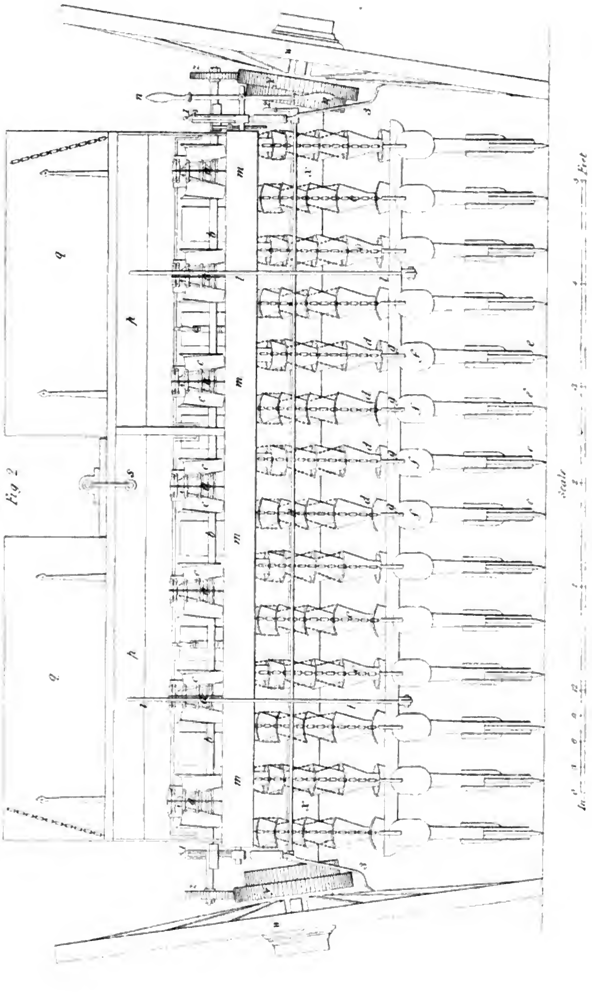
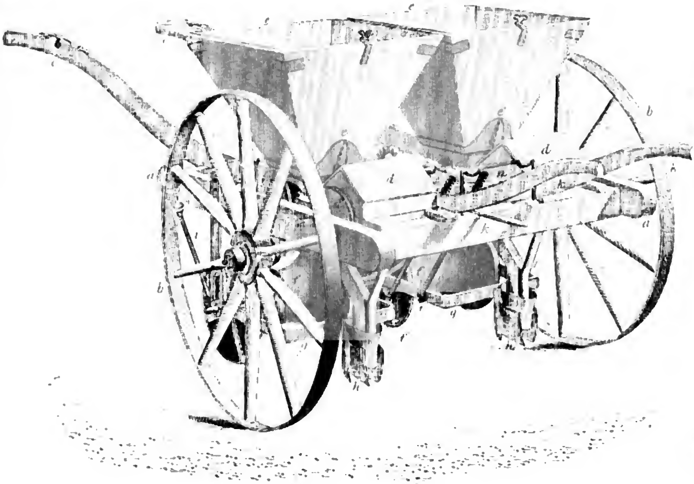


PLATE XVI

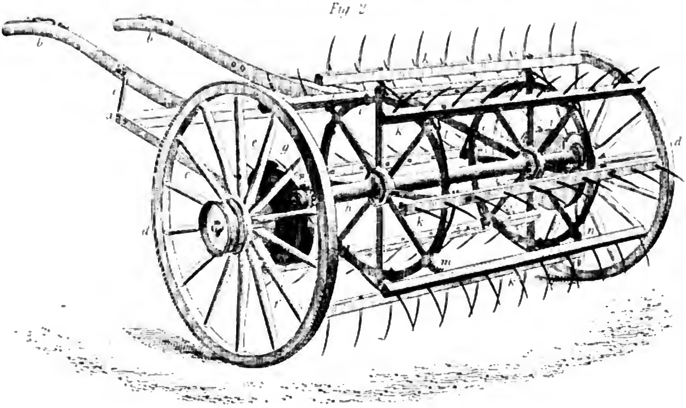
TURNIP & BONE DUST DRILL.

Fig. 1



HAY TEDDING MACHINE.

Fig. 2



G. H. Slight del.

W. H. Lizars sculp.

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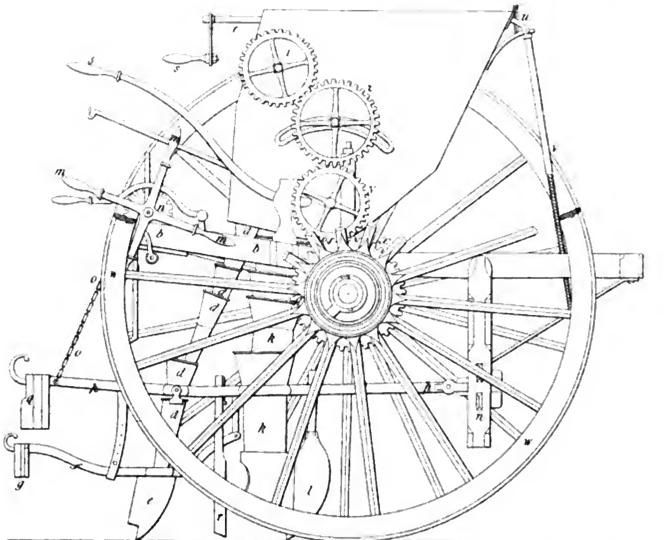
GARRETT'S SEED AND MANURE DRILL.

Fig. 1



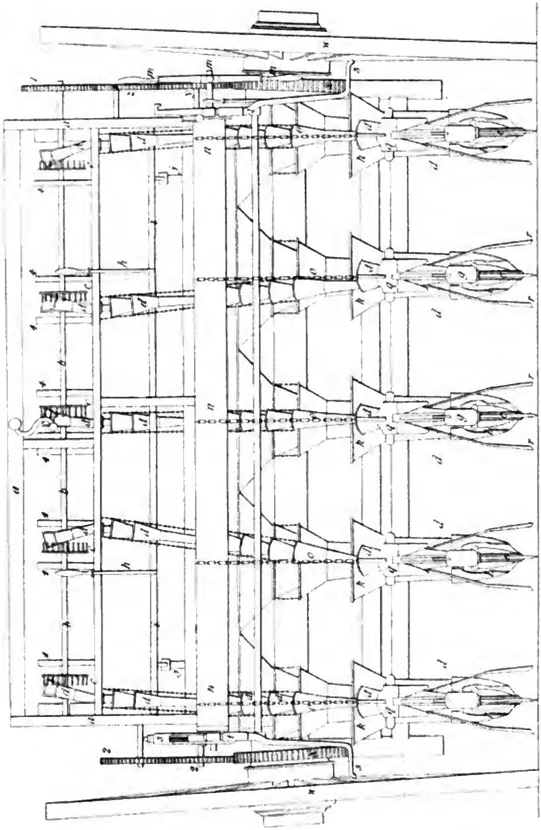


Fig. 2

Scale

GARRETT'S SEED AND MANURE DRILL.

Fig. 1

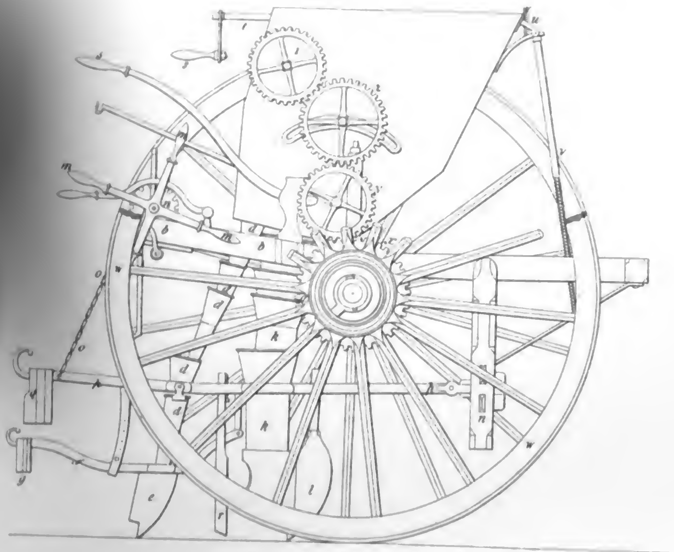


PLATE XVII

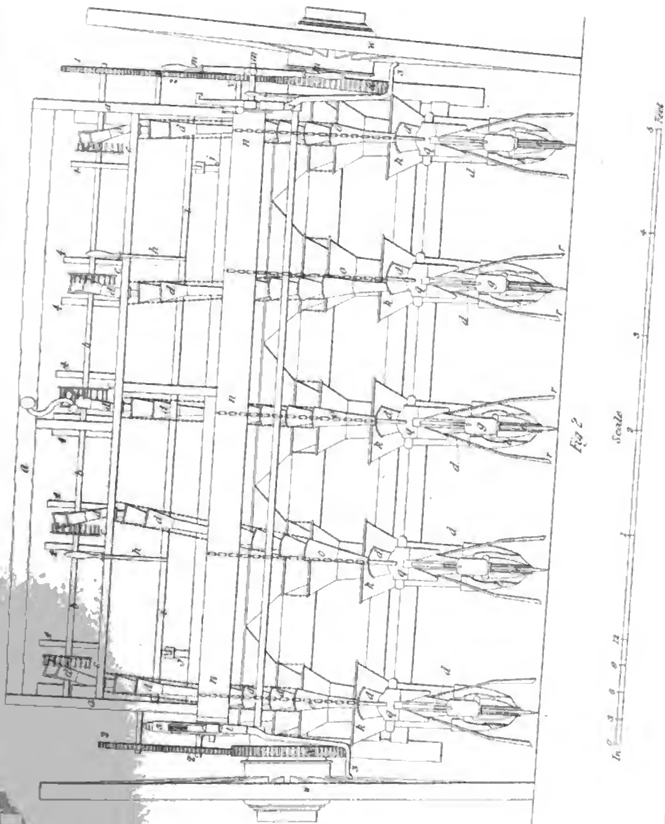


Fig. 2.

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LIQUID MANURE AND SEED DROP-DRILL.

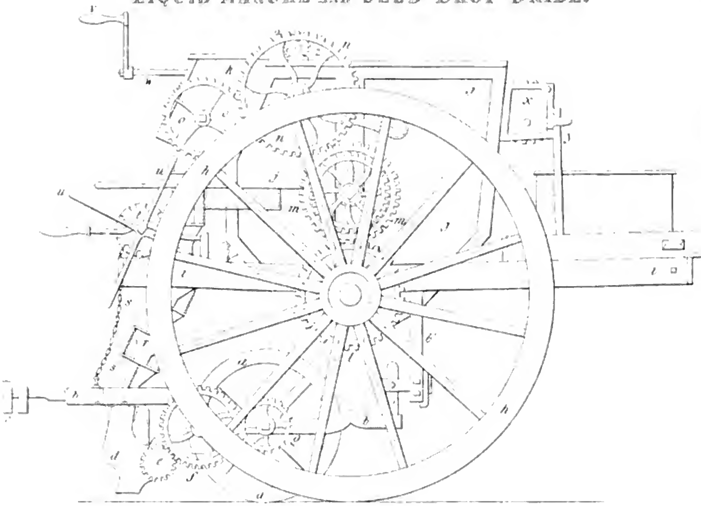


Fig. 1

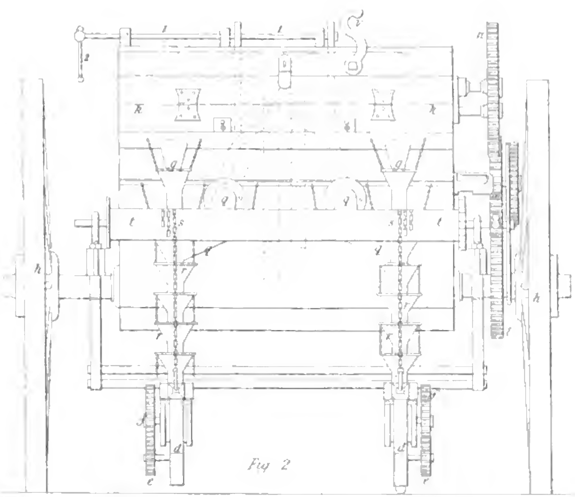


Fig. 2

Scale

CHAMBERS' BROAD-CAST MANURE DISTRIBUTOR. PLATE XIX

Fig 1

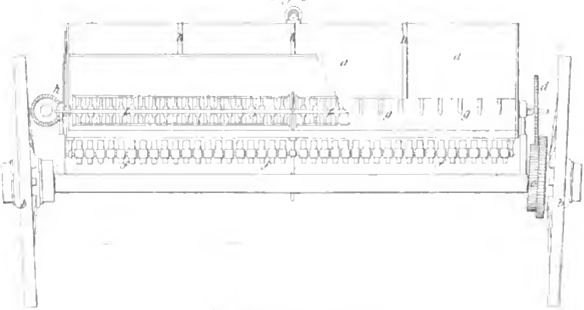


Fig 2

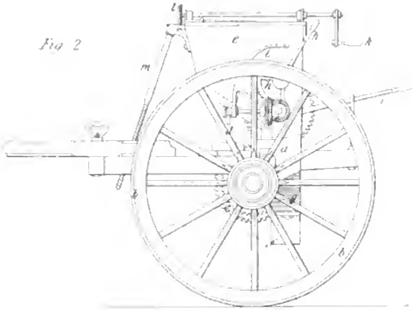
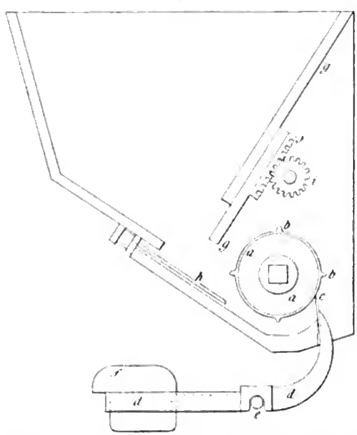


Fig 3



Scale for figs 1 and 2 1½ Inch = 1 foot Fig 3 ½th of full size

R S R Direx.

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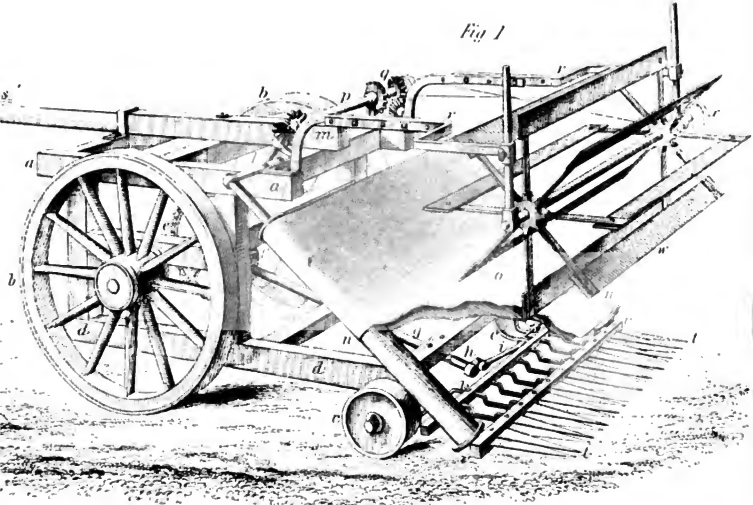
BELL'S REAPING MACHINE.

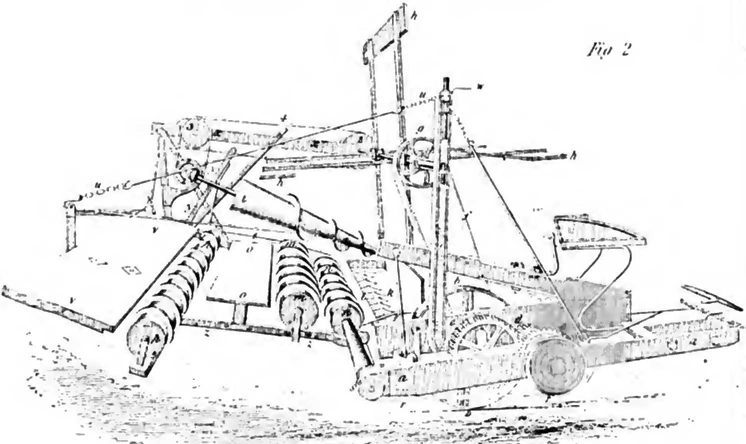
PLATE XX

Fig 1



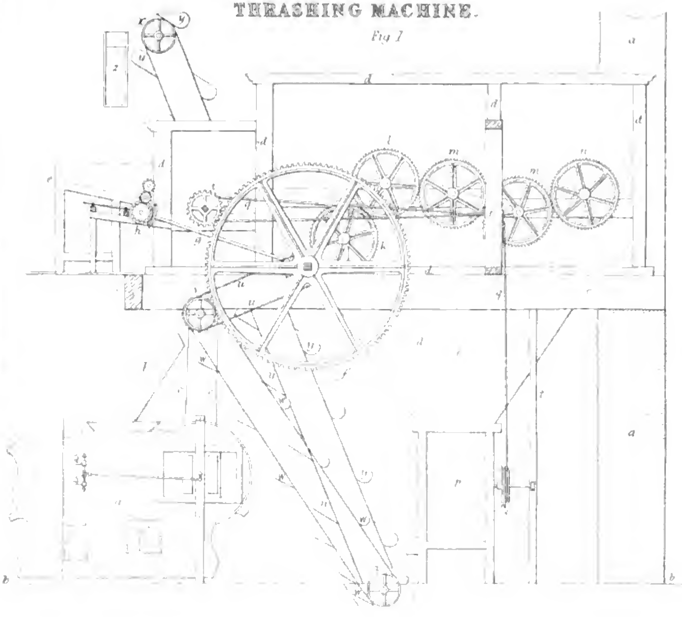
MC CORMICK'S REAPING MACHINE.

Fig 2



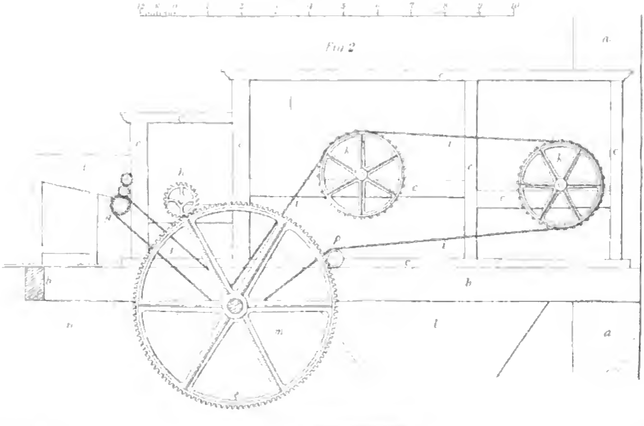
THRASHING MACHINE.

Fig 1



Scale of Feet

Fig 2



E. S. Bright delt | W. H. Lizars sculpt

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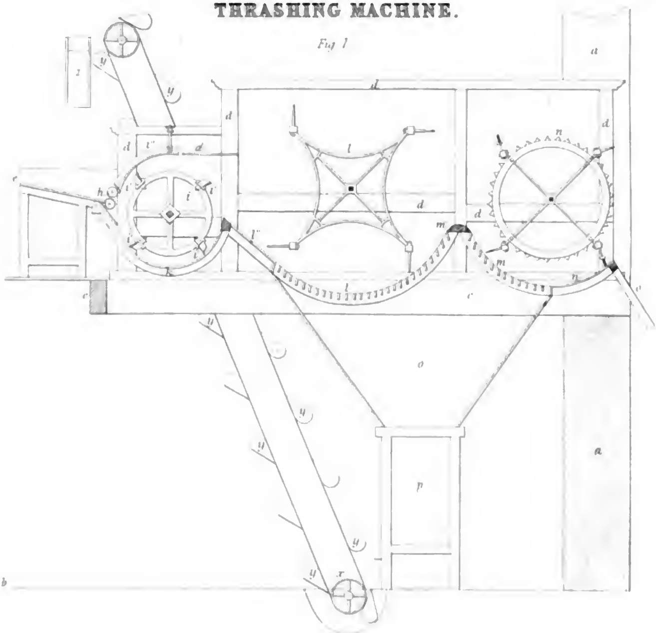
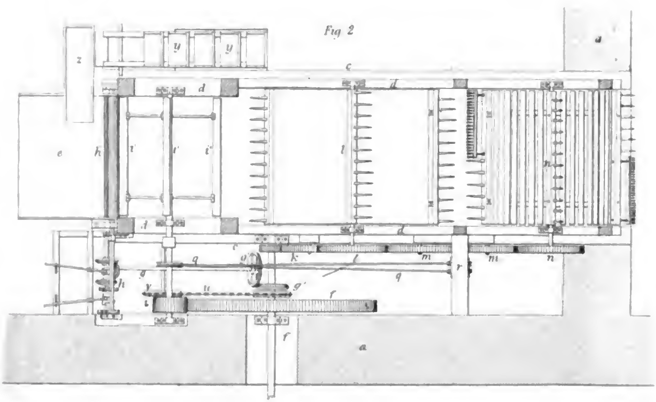
THRASHING MACHINE.

Fig 1



Scale of Feet

Fig 2



G H Slight del^t

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PLATE XXIII

DRAY'S TWO HORSE AND FOUR HORSE PORTABLE THRASHING MACHINE.

Fig 1

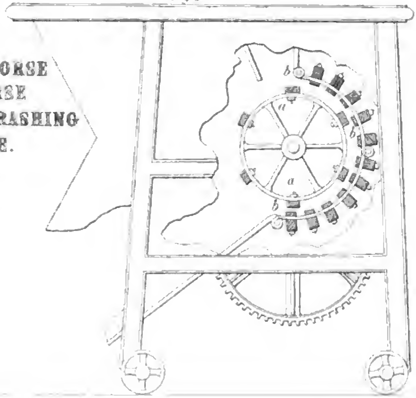
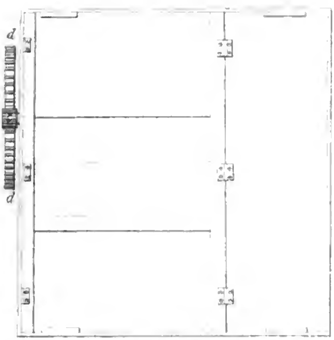


Fig 2



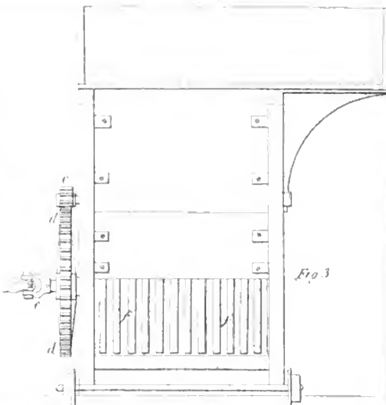


Fig 3

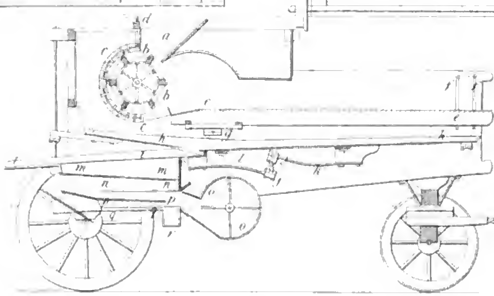
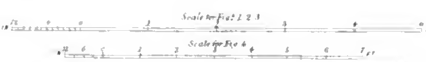


Fig 4



Gomes Del

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GARRETTS PORTABLE THRASHING MACHINE.

Fig 1

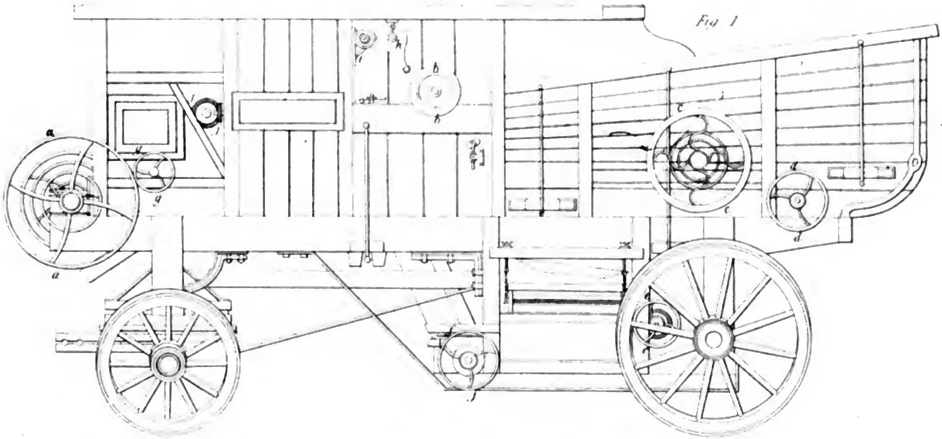


Fig 2

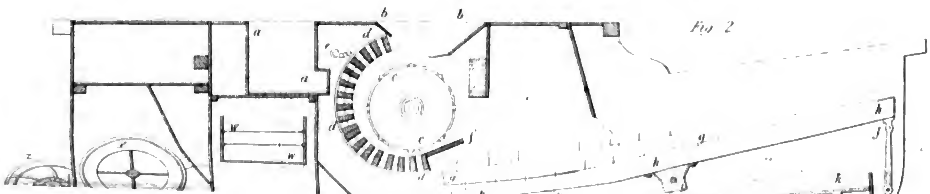
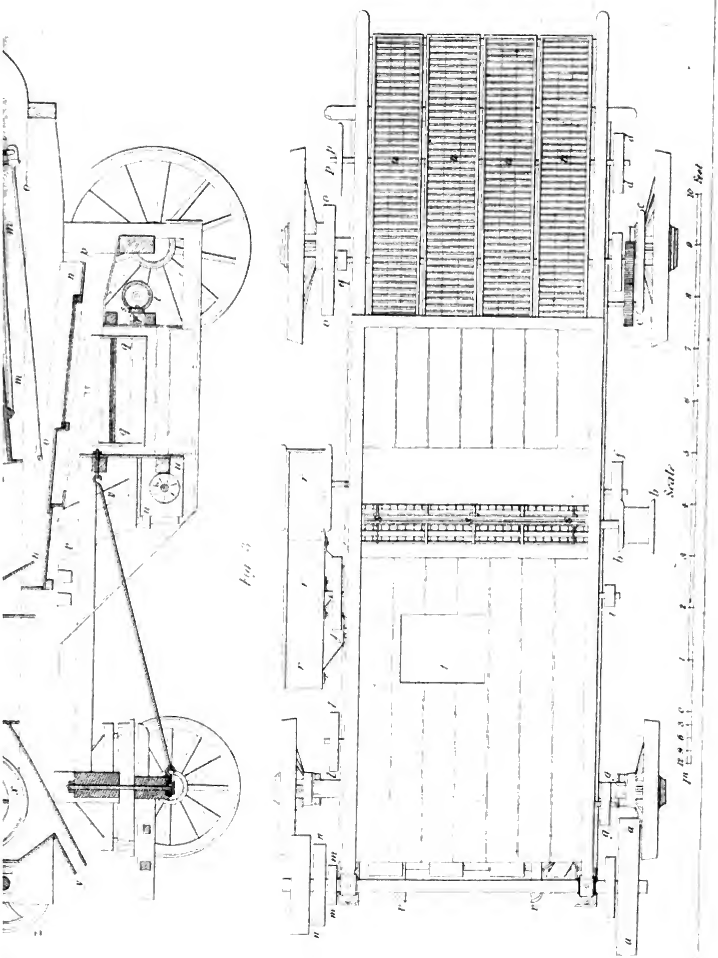


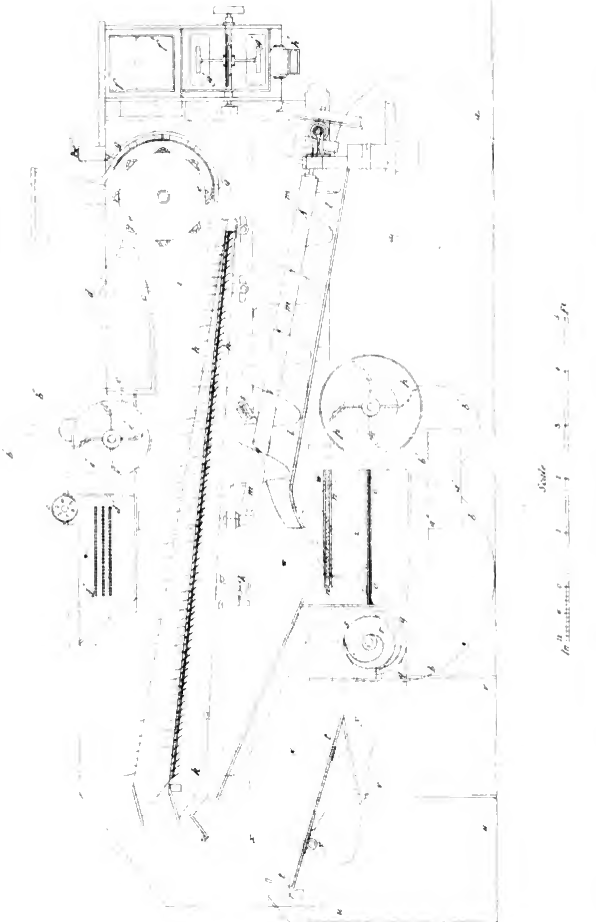
PLATE XXIV



...wood & Sons Edinburgh & London.

PLATE XXV

HORNSBY'S THRASHING MACHINE.



R & R sculpt

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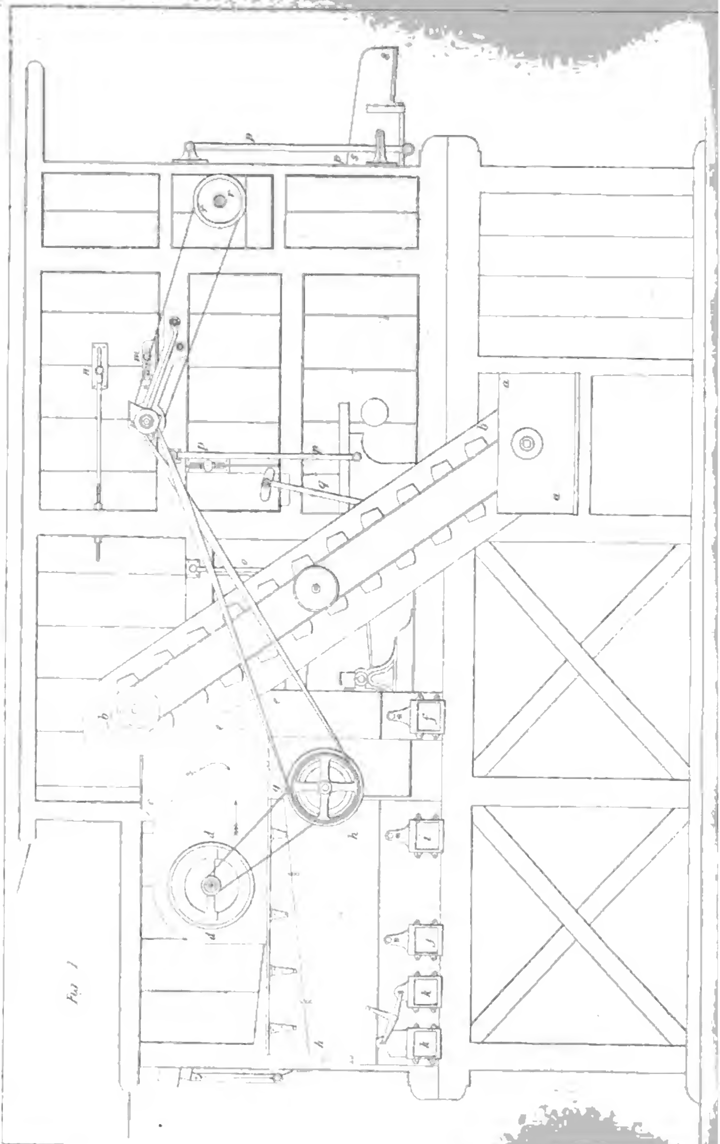

Fig. 1

R. S. B. Direx

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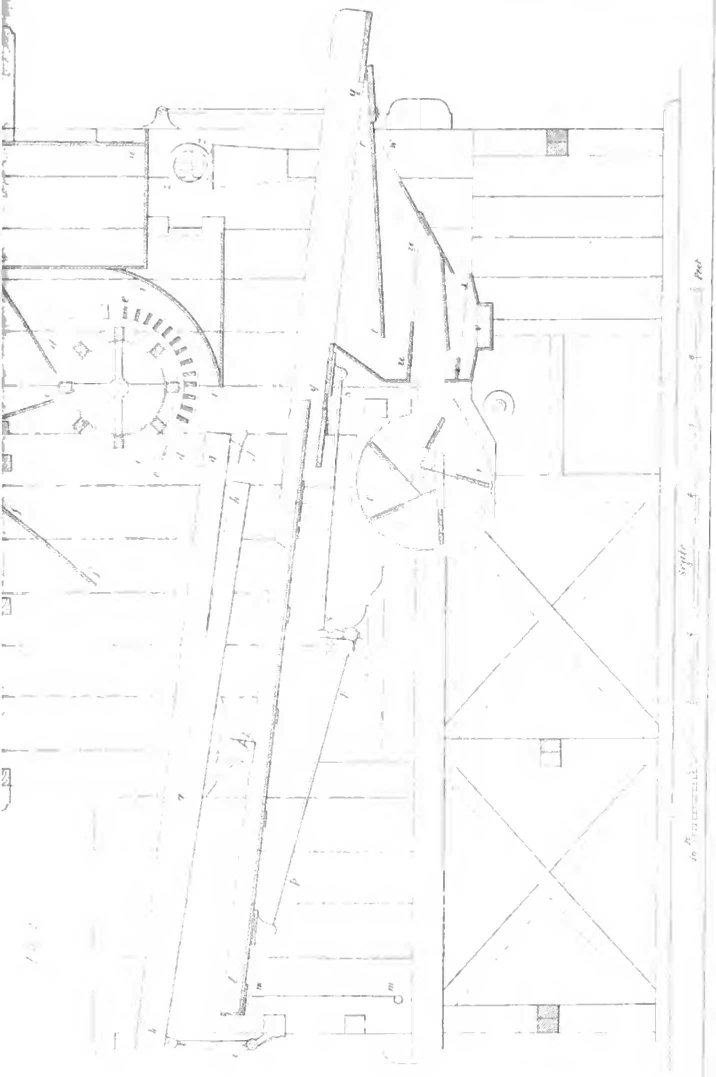
PLATE XXVI



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DRAY'S CORN DRESSING MACHINE PLATE XXVII

Fig 1

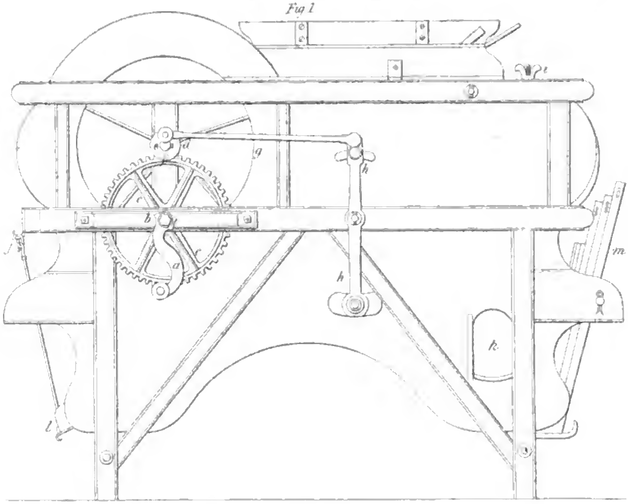
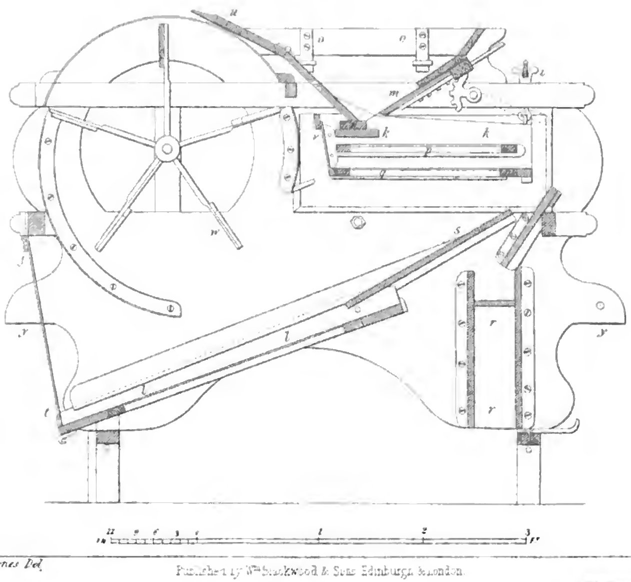


Fig 2



C. Cornes Del.

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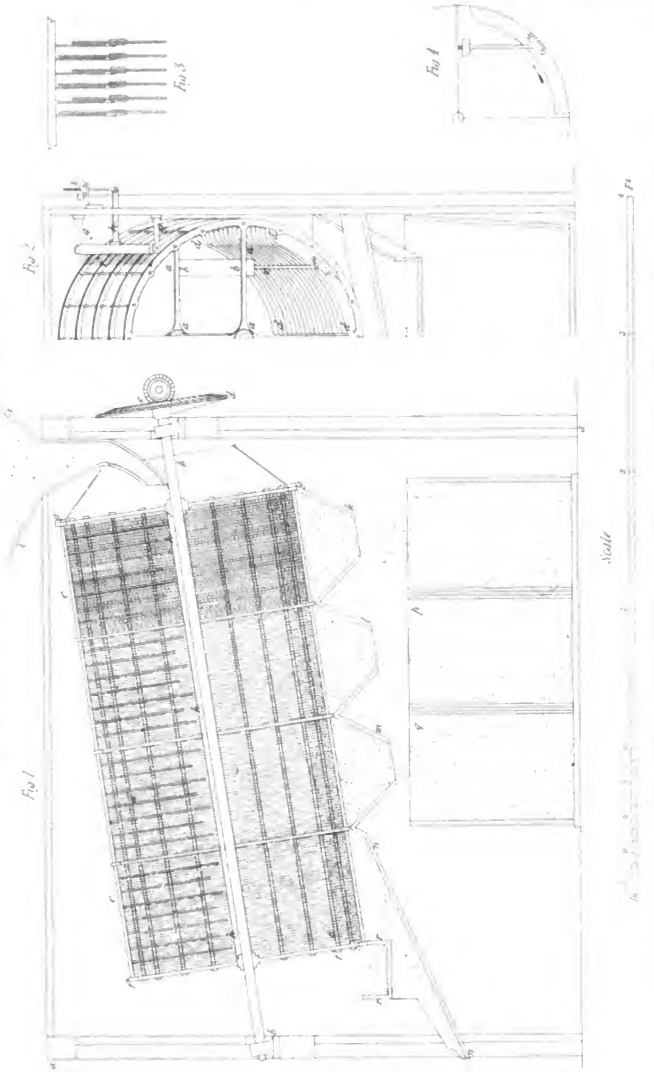
PALMER'S ROTATORY CORN SEPERATOR



R.S.B. Direx

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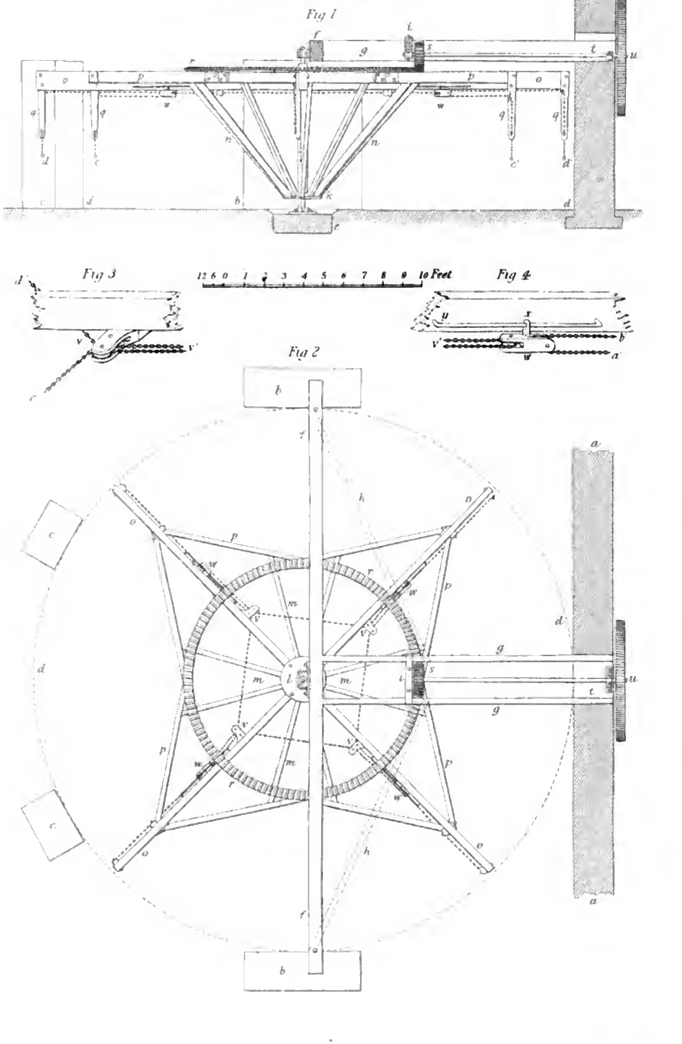
HORSE WHEEL.



E S Leight delt — W.H.Lizars sculpt

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Fig 1

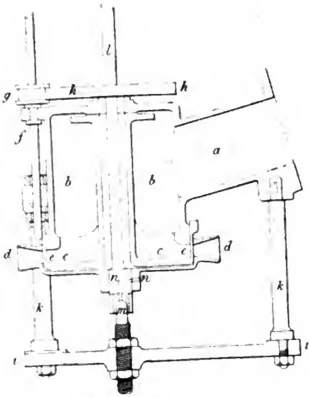


Fig 2

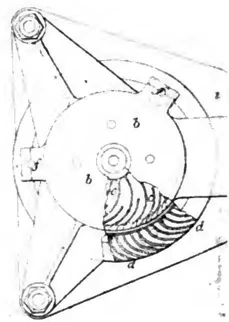
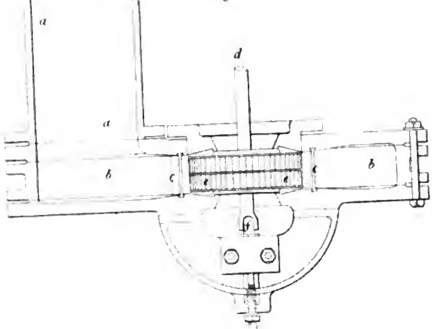
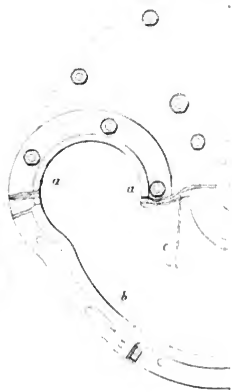


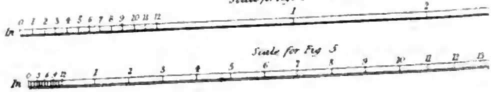
Fig 3





Scale for Fig's 1 2 3 and 4

Scale for Fig 5



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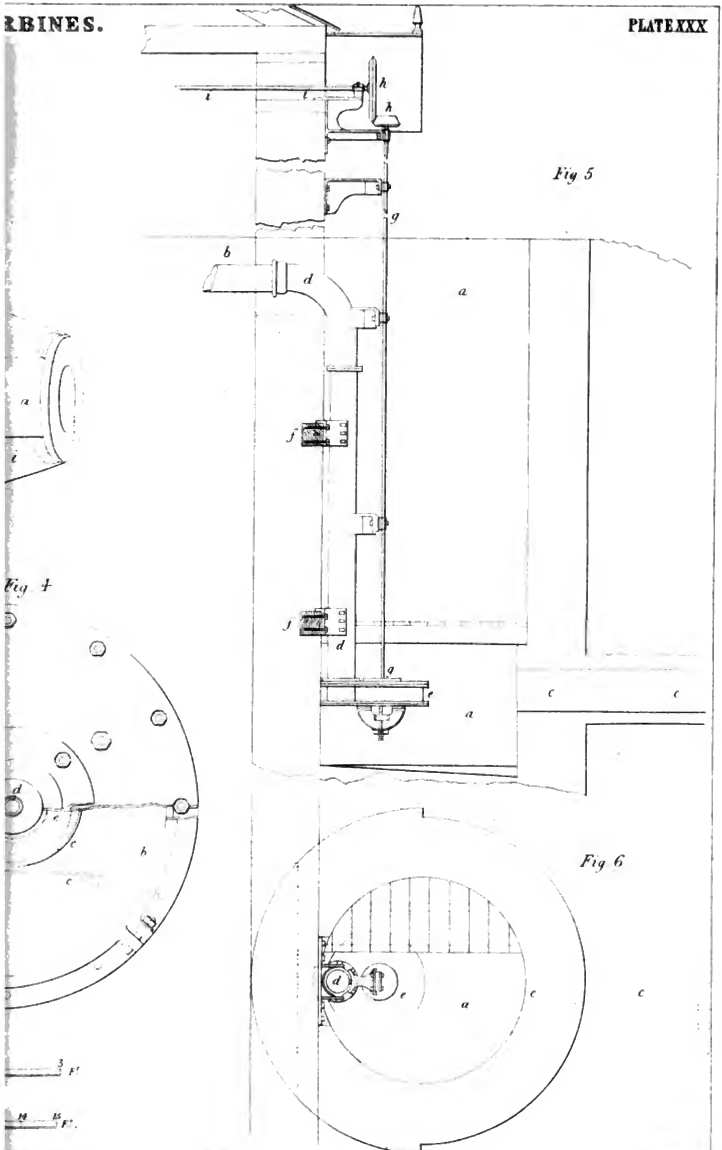

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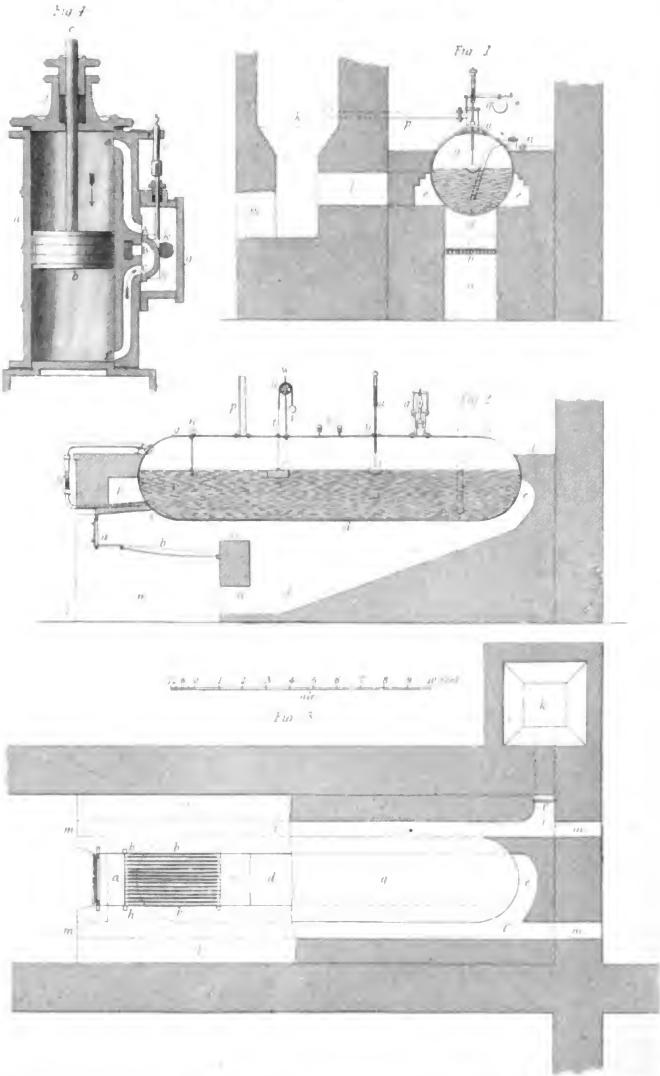
STEAM ENGINE BOILER.



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MULTITUBULAR STEAM BOILER.

PLATE XXXII

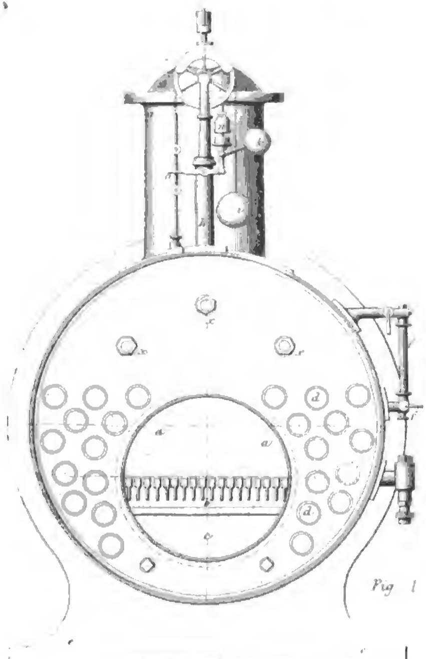


Fig 1

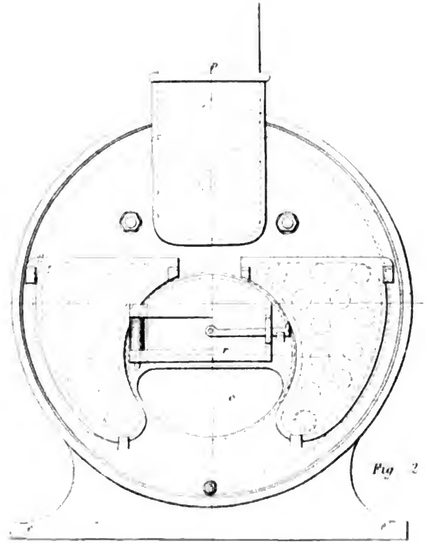
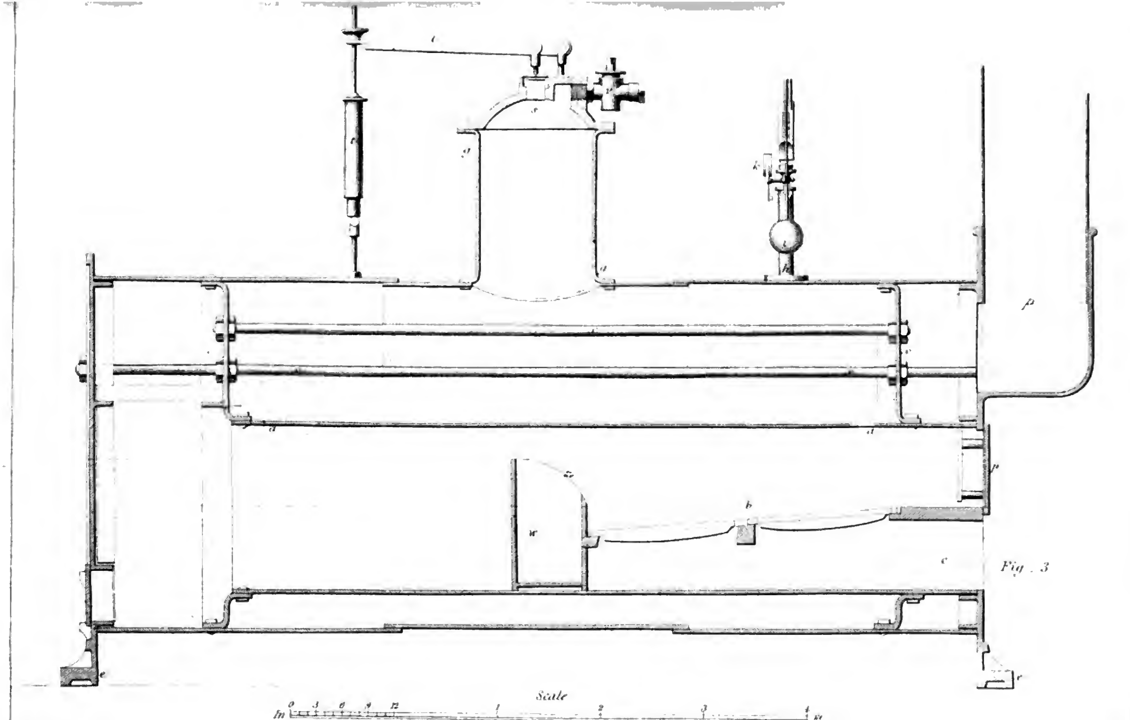


Fig 2



R.S.B. Direx

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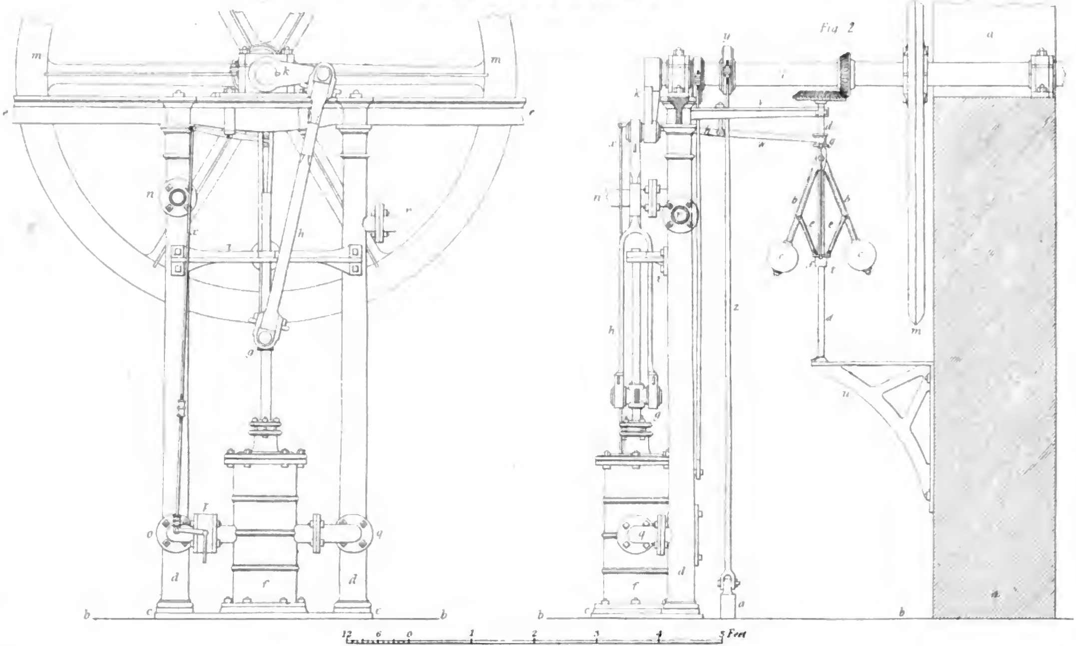
CRANK STEAM ENGINE.

Fig 1   Fig 2



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BEAM STEAM ENGINE.

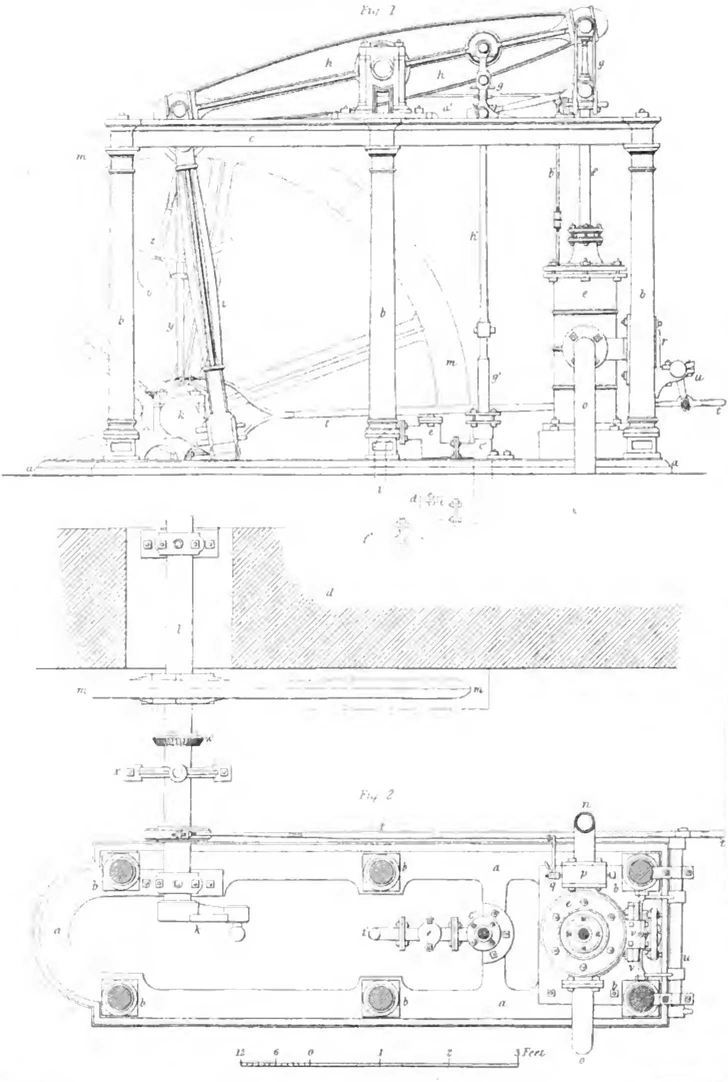

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PLATE XXXV

CONDENSING S

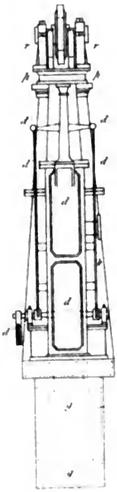


Fig 4

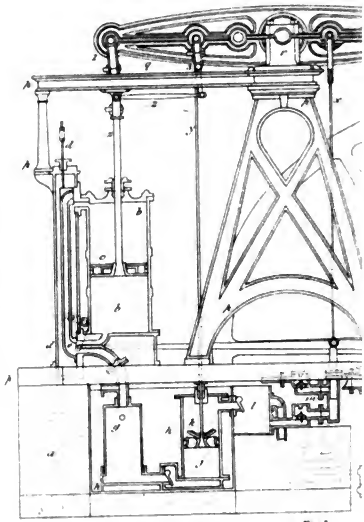
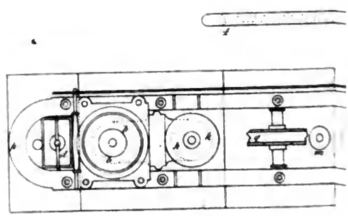


Fig 1



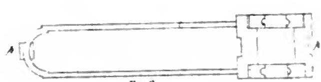


Fig 3

SCALE o

K. S. & Sc.

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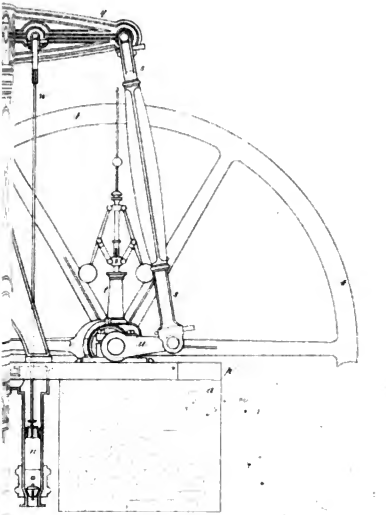

Fig 5

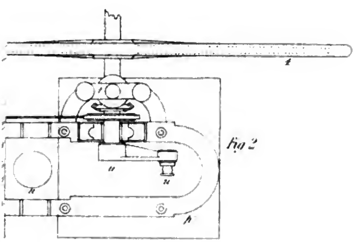

Fig 2

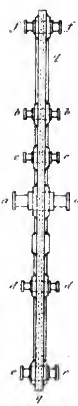

Fig 6

OF FEET

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HORIZONTAL HIGH PR

Fig 1

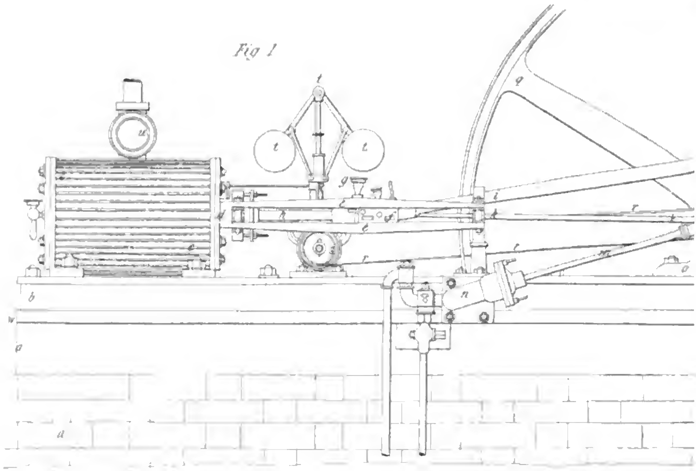
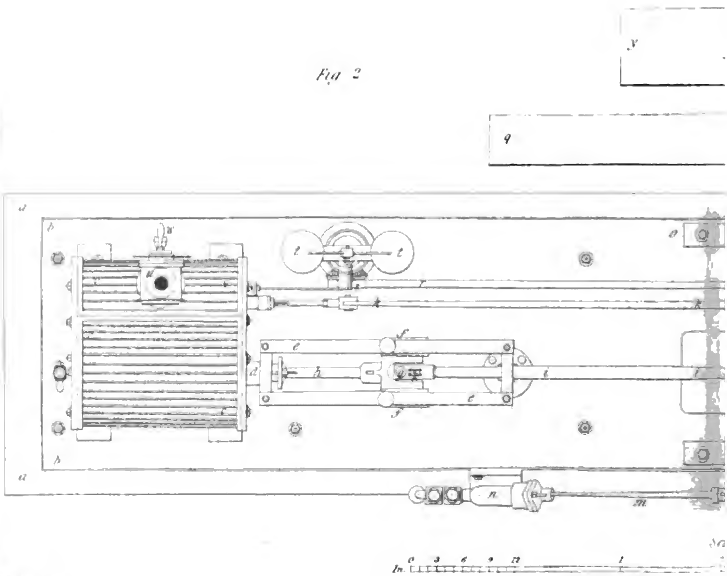


Fig 2



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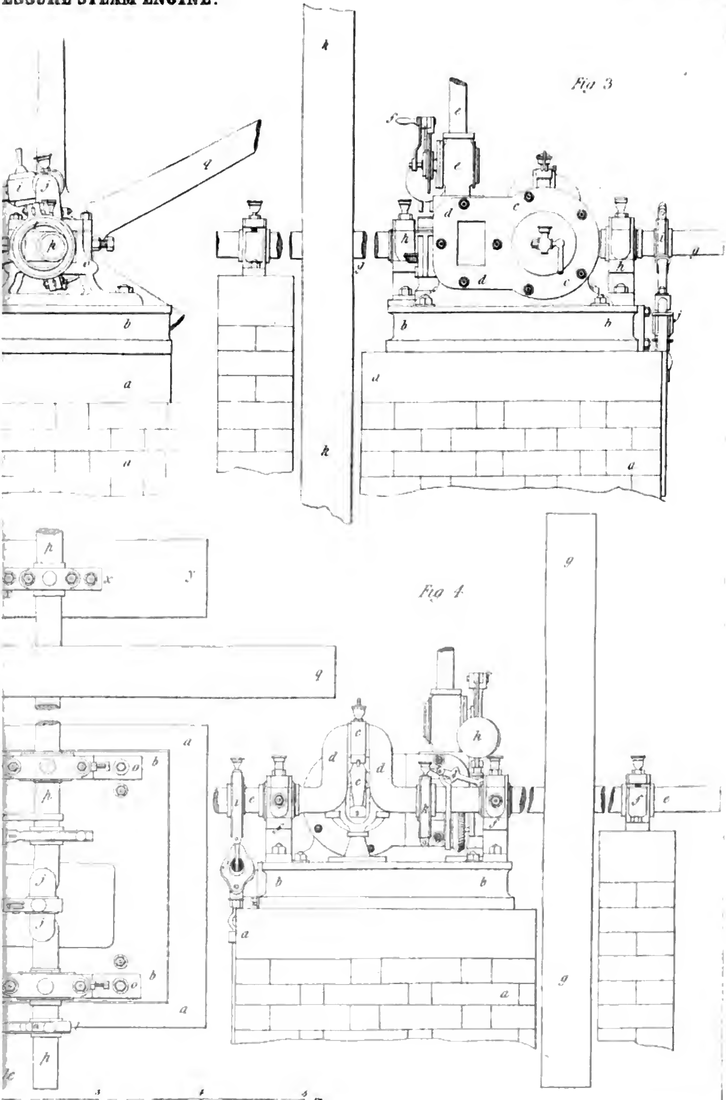


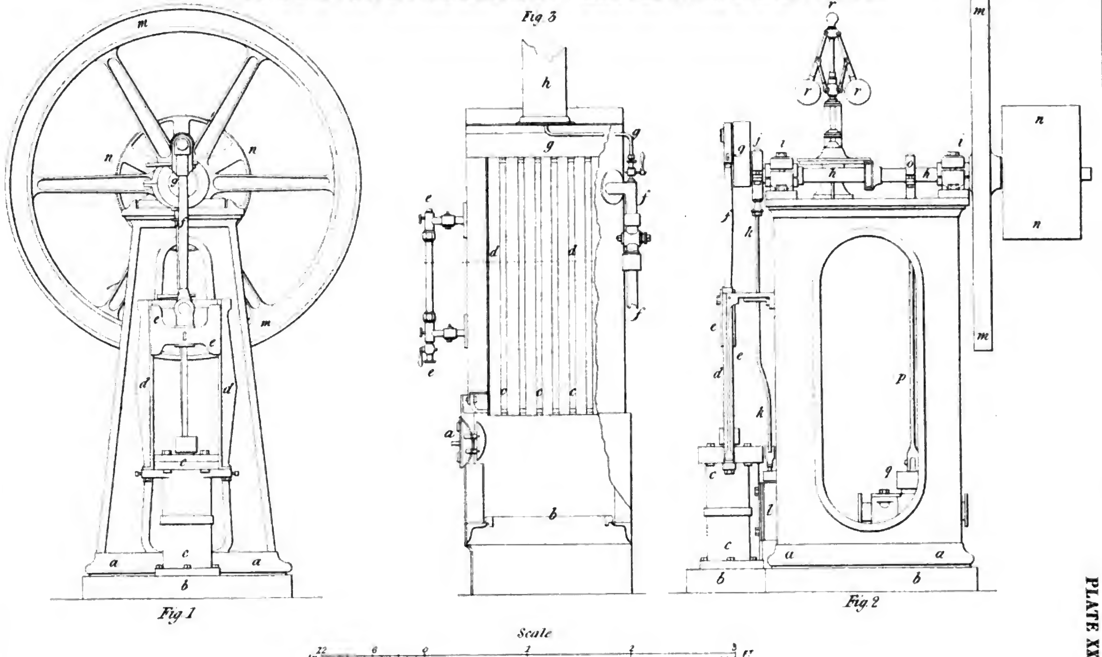
Fig 3

Fig 4

a Edinburgh & London.

PLATE XXXVII

PORTABLE CRANK-OVER-HEAD HIGH PRESSURE STEAM ENGINE & BOILER.



R.S.B. Direx.

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TUXFORD'S PORTABLE STEAM ENGINE.

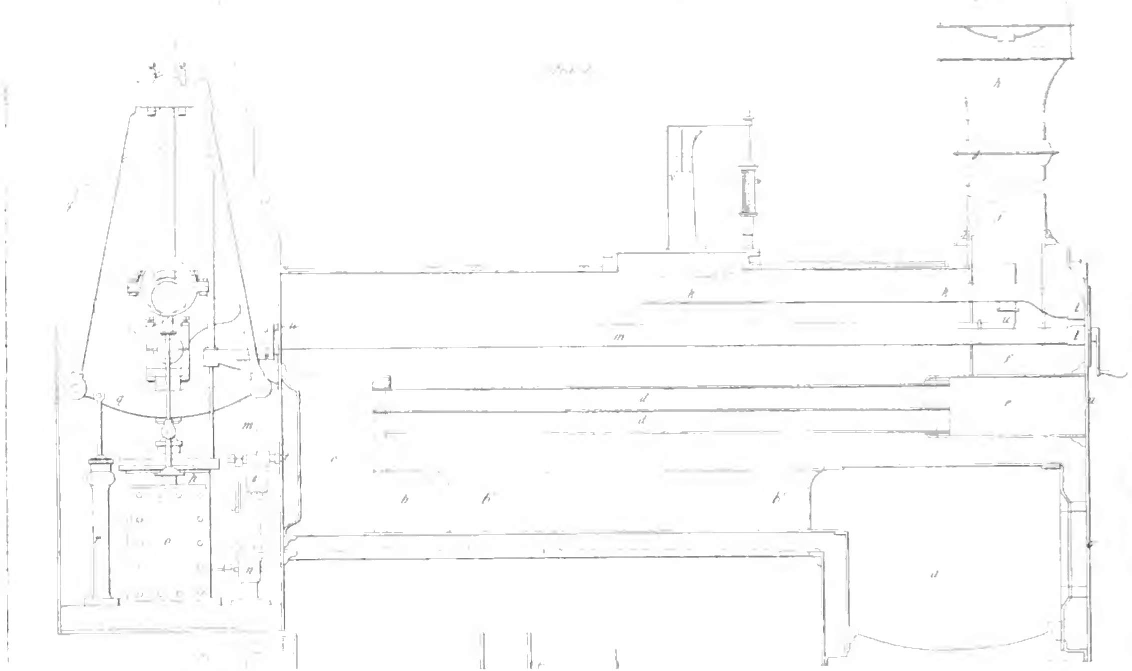


Fig 2

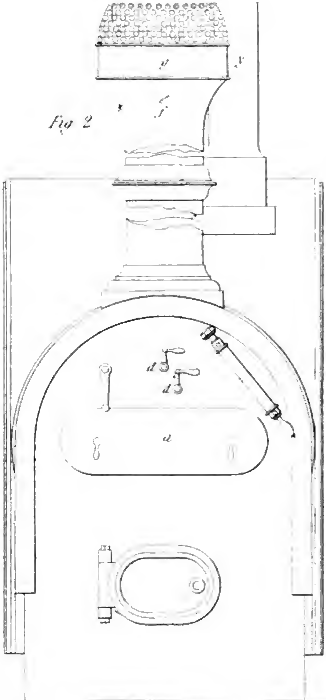
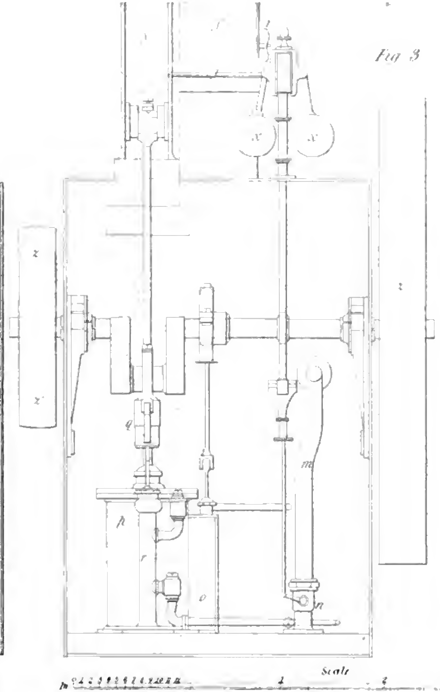
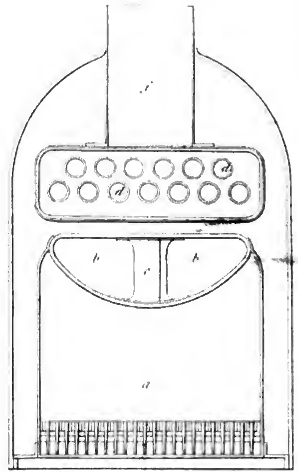


Fig 3



Scale

Fig 4



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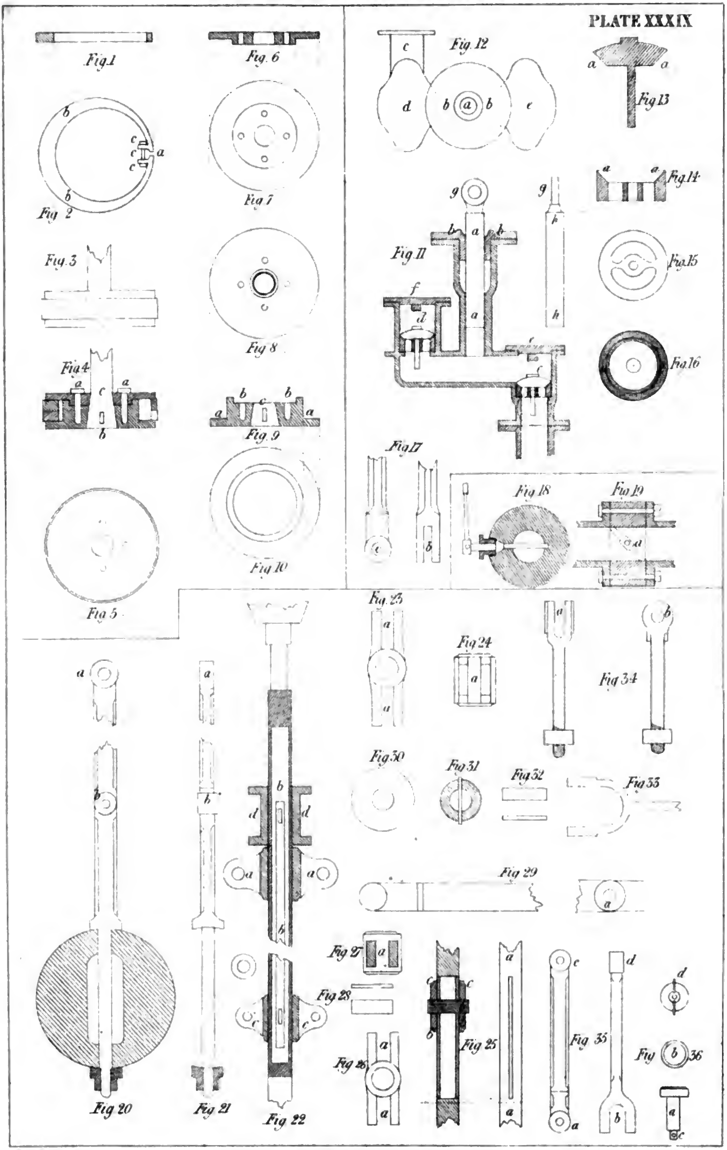
DETAILS OF CRANK STEAM ENGINE



R. S. B. Direx

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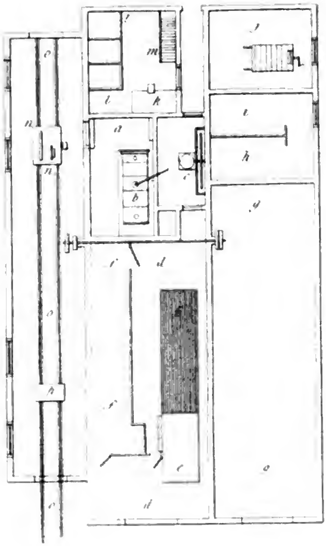
Fig 1



ARRANGEME

ST

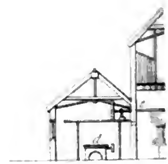
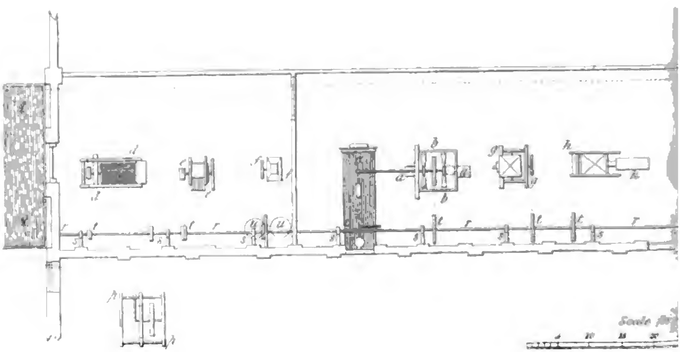


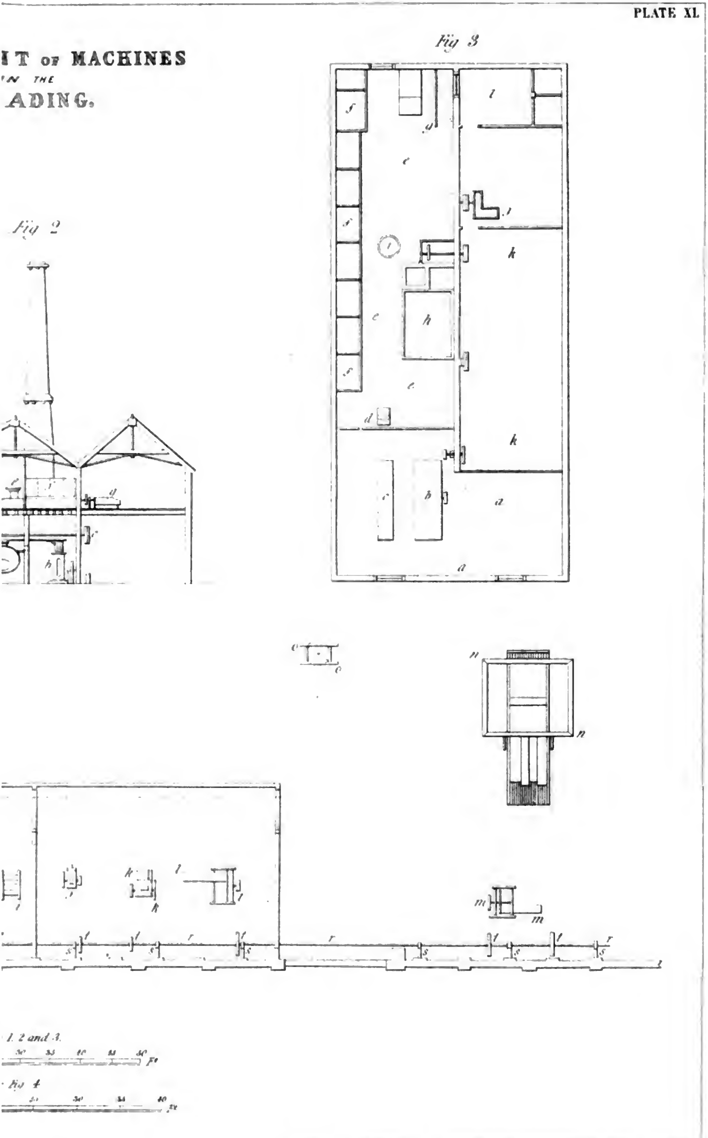
Fig 4



Scale

Scale

Published by W^m Bi



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