THE COMPLETE TEXT-BOOK

OF

FARM ENGINEERING

COMPRISING

PRACTICAL TREATISES

ON

DRAINING AND EMBANKING; IRRIGATION AND WATER SUPPLY · FARM ROADS, FENCES, AND GATES; FARM BUILDINGS; BARN IMPLEMENTS AND MACHINES; FIELD IMPLEMENTS AND MACHINES; AND AGRICULTURAL SURVEYING

WITH UPWARDS OF SIX HUNDRED ILLUSTRATIONS

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SCOTT'S FARM ENGINEERING TEXT-BOOKS

I.

DRAINING AND EMBANKING

A

PRACTICAL TREATISE

EMBODYING

THE MOST RECENT EXPERIENCE IN THE APPLICATION
OF IMPROVED METHODS

PREFACE.

The present volume is the first of a series which will comprise the following—Draining and Embanking, Irrigation and Water Supply, Roads and Fences, Farm Buildings, Field Implements and Machinery, Barn Implements and Machinery, and Agricultural Surveying.

The existing literature on these subjects is by no means sparse, but there is no work of recent date which deals with them in a complete or connected form; while the old text-books on such matters, however good they may have been in their day, are now rendered more or less obsolete and untrustworthy, by reason of the great advances which have been made in agricultural science and mechanics within the last few years.

To bring forward all recent information and improvements in connection with the subjects treated of, and to preserve all that is good and practicable, while avoiding what is obsolete or misleading, in the older text-books, will give ample scope and fitting material for the work here begun.

In regard to Land-drainage, which forms the main topic of the present volume, it is abundantly clear, from the effects of a few wet years, that not only is there great need of its extension, but that serious deficiencies exist in much of the drainage already done, and that in the majority of cases the improvement is less durable than it has been common to suppose.

There is very little land that is not in need of draining. For the object of drainage is not merely to dry land, and to carry off the surplus water, but also to let water into the soil, to enrich the soil by taking advantage of the fertilising rain, to counteract drought, and to create a healthy renovation of both air and water, from the surface downwards to the drain level.

The failure of drainage, in certain instances, to lay wet land sufficiently dry for cultivation or stock-raising, is found to be attributable to such causes as errors in principle, rule-of-thumb work, and neglect to cultivate deeply after draining; and a revision of the practice of land-drainage is the natural outcome of the experience thus recently gained.

The once much controverted question of deep or shallow drains has in effect settled itself, and in favour of no particular theory. Experience has taught those interested in the problem, that in order to drain successfully, the depth of the drains must be regulated by the width or distance between them; and that again by the nature of the soil and subsoil; while the cost of the improvement puts a practical limit to both the depth and frequency of the drains.

Another change in the practice of draining is the employment of larger-sized drain-pipes than it has hitherto been customary to use.

The increased cost of labour is forcing attention to the economy of moving the least possible quantity of earth in cutting the drains, and of superseding hand cutting by machine draining as far as practicable.

Embanking is treated of in the same volume, from its being a necessary preliminary to the drainage of tidal lands.

NOTE TO THE SECOND EDITION.

In this Edition some clerical errors have been corrected, and a few explanatory paragraphs added in the body of the book. While the Appendix has been enlarged by the addition of a short description of a Drain Pipe Machine.

CONTENTS.

LIST OF ILLUSTRATIONS.

DRAINING AND EMBANKING.

CHAPTER I.

REASONS FOR DRAINING LAND.

LAND-DRAINAGE, by which we signify the art of removing the excess of water from the soil, appears to have been practised, in one form or another, nearly as long as agriculture itself. Open channels would first naturally suggest themselves as the easiest means of relieving the soil of superabundant moisture. But as land increased in value, and the number of trenches had to be multiplied, it would soon be felt that by covering over those open channels they would still perform their office, and yet leave the space occupied by them available for tillage and cropping. There are other reasons, as the sequel will show, why under-draining is preferable to open or surface draining.

Objects of Draining.—The primary objects of under-draining undoubtedly are—to carry off stagnant water; to give a ready escape to the excess of what falls in rain; and to arrest the ascent of water from beneath, whether by springs or by capillary action; so as to render the land sufficiently dry for cultivation, and at the same time regulate the supply of moisture to the growing plants.

But the purpose of under-draining is not merely to let water out of the soil. We drain to let water into the soil, as much as to take it out—not merely to carry off the surplus water, but to make the fertilising rain filter through the soil. "No farmer worthy of the name," says an authority, "would wish to conduct rain-water off his land by surface grips, or have recourse to under-draining simply to tap the soaking subterranean springs."

Effects of Drainage.—"When there is an excess of water in a soil, and no provision exists for withdrawing it, the interstitial canals become completely filled, to the exclusion of the necessary amount of air, on which the activity of the soil considered as a laboratory for the production of plant food depends.

"When the soil is under-drained, the superfluous water flows off through the air canals, and only so much moisture is retained as can be absorbed by the minuter pores of the soil; and as there is, then, free communication, through the canals, between the pores and the drains, it is evident that the water will all be withdrawn from the soil except that which is held by capillary attraction. Thus the rain which falls upon, and is absorbed by, the surface ground, percolates towards the drainage level, flushing every crevice and canal in its descent, leaving behind it the nutritive ingredients which it carries in suspension or in solution, and on which the plants can feed as it passes by their roots, or which the soil, acting as a filter, extracts and appropriates."

According to Way, the total quantity of nitrogen, in the form of ammonia and nitric acid, brought down by rain and snow upon an acre of land in the year, was found to be 6·63 lbs. in 1855, and 8·31 lbs. in 1856.

Under-draining not only allows the rainfall loaded with this fertility to pass through the soil and be discharged from underneath, after depositing its fertilising material, instead of flooding the surface and removing from the upper soil many substances useful to vegetation; but the rain-water in sinking down through the soil oxidises and washes out of it anything that may be hurtful to the roots of plants; and the solvent action of the rain-water is, at the same time, brought to bear upon the inert constituents of the soil and of the manures with which it is brought into contact. The latter is not the least benefit of draining, for on wet land the best manures are almost thrown away.

"This constant descent of water through the soil causes a similar descent of air through its pores, from the surface to the depth of the drain. When the rain falls it enters the soil, and more or less completely displaces the air which is contained within its pores. Thus air either descends to the drains, or rises into the atmosphere. When the rain ceases, the water as it sinks again leaves the pores of the upper soil open, and fresh air consequently follows. Thus, where under-drains exist, not only does every shower deposit its fertilising ammonia, but it serves to force the fresh air through the pores, which produces conditions so healthful to vegetation."

Under-draining deepens the soil by lowering the line of excessive water beyond injury to the roots. It affords to plants a deeper soil for their roots to penetrate, at the rate of 100 tons per acre for every inch of depth gained. It prepares the way for deep tillage and steam cultivation. It improves the texture of the soil by making it more porous, drier, looser, and more friable; and it thus not only gives greater ease in tillage operations, but admits of the land being worked sooner after a fall of rain. The difference in labour between ploughing drained and undrained land is very considerable, and at the lowest estimate cannot be put at less than one shilling per acre for each ploughing.

Thorough drainage not only relieves a soil of excess of water, but, strange as it at first appears, it greatly mitigates the effects of dry weather. When soil is drenched with water and dried by evaporation, it becomes hard, especially if it be of a clayey nature. Land that is dried by drainage is absorbent and retentive of moisture dropped by dews and acquired from the atmosphere; while the soil deepened by drainage permits growing crops to put forth longer roots, and thus become secured against drought.

By drainage, the temperature of the soil is raised in summer as much as 3°, which is in effect to transport the land 150 miles southwards. The soil is thus enabled to grow a greater variety of crops than it would do in its undrained state. Less seed is required in sowing, because fewer seeds perish than when they are put into a saturated soil where the temperature is lower, and from which the air necessary to germination is excluded. It prevents in a great measure grass and winter grains being killed or thrown out by frost. An earlier seed-time and harvest are also accompaniments of drained land; the season being hastened in the spring by the land drying sooner, and enabling the cultivator to get on his land earlier by several days, a start which is maintained by the crop all through the summer. A week at seed-time or harvest often makes all the difference between the success or failure of a crop.

"In all cases the end desired is the nearest possible approach to the natural examples of the best soils resting on pervious subsoils, where the rainfall finds a gradual passage through the soil and subsoil, sinking always where it falls, carrying generally the warmer temperature of the air into the land—carrying also many an element of plant food, which the air contains, directly to the roots of plants—carrying, too, the air itself, the great oxidiser, amidst the matters, organic and inorganic, which require its influence for their conversion into available plant food, proving, by its action as a solvent, and its passage over the immense inner superficies of the soil, an active caterer for the stationary roots. At the same time it is hindered from doing the mischief which on undrained land the rainfall cannot fail of doing. The manure particles of the soil, if they do to some extent escape through drainage, are at any rate not washed wholesale from the surface into the furrows, ditches which, in the case of undrained land, receive them without the subsoil having had a chance of retaining them."*

One of the benefits of under-draining is that, besides letting off water which would stagnate in the operation, the finer parts of the soil are washed in instead of out, while the water which is discharged extracts a comparatively small portion of the soil. At the same time there may be some loss of soluble nitrogen occasioned by drainage.

Loss of Nitrates by Drainage.—On comparing the composition of the manure applied to land at Rothamstead with the composition of the crops that were carted off, it was found that from one-half to two-thirds, and more at times, of the supplied nitrogen was missing. Analysis of the soil failed to account for the missing nitrogen. A considerable part of it was, indeed, found

* "Soil of the Farm."

to be actually present in the soil, but it appeared to be in some state of combination unsuitable for the plants' use, as it had scarcely any effect on the crops. A still larger portion of the nitrogen was, however, not to be found in the soil; but analysis of the drainage water gave so large a content of nitrates, as to lead on to the discovery that the loss of nitrogen chiefly takes place through the drains. Knowing that ammonia is readily absorbed and firmly held by most soils, it had never been anticipated that so great a loss might occur by drainage. These investigations, however, clearly showed that ammonia, when applied to the soil, is quickly converted into nitric acid, and in heavy rains is easily washed out. This is particularly the case with ammonium salts and nitrate of sodium; but it is true of all nitrogenous matters or manures within the soil; they are readily convertible, under certain conditions, into the soluble form, which renders them specially liable to waste.

Sir J. B. Lawes has calculated that if the drainage water contains only one part of nitrogen in 100,000, there will be a loss of nitrogen equal to about 23 lbs. of guano for every inch of rain that makes its escape through the drains. This loss is greatest during winter and autumn, when there is little evaporation from the soil and no consumption of water by a growing crop. The best safeguard against such loss is in the absorbent power of the soil itself; but means may be adopted for diminishing the loss by a system of winter cropping. The growing crop not only absorbs and throws off into the atmosphere a portion of the rainfall, thus lessening the drainage, but it arrests the vagrant nitrogen, and stores it up in its roots, to be made use of by itself or by another crop the following spring; and if the crop grown be a deep-rooted one, the advantage will be all the greater, as it will then bring nitrogen from the subsoil to the surface.

Alleged Over-draining.—The opinion is often expressed, even by practical men, that it is possible to lay land too dry by means of underground drains; and numerous examples of grass lands so injured have been cited. The effect of drainage upon grass lands is of course to bring about a change in the herbage, the water grasses and sedges common to wet land giving place to the grasses proper to dry land; but it will generally be found that, where any diminution in the produce of the land has followed drainage, it is only of a temporary character, and has probably resulted from a period of drought occurring during the change of herbage, just after the water grasses had died out and before the grasses proper to dry land have had time to establish themselves. If rain fell throughout this period of change the result would show to the advantage of drainage, just as it invariably does on grass lands which have been drained for any length of time, and on arable lands. The idea that land can be made too dry by any number of drains need not be entertained. That it is possible to make the depth of the drains beyond the capillary powers of the soil is true enough; but beyond this it is impossible to over-drain land. "The extent to which a soil can be made dry is dependent not merely on the drainage, but also to a very great extent upon its power of retaining water, in regard to which different soils vary within very wide limits. In order to illustrate this point, let us suppose a very fine sieve to be filled with a dry soil, and water to be poured upon it. The water of course will trickle through the soil, and the greater part escape by the meshes of the sieve; but a certain quantity, dependent on the texture of the soil, will always be retained within its pores by capillary attraction. The former will represent that portion of water which flows off by the drains, while the latter will never enter them at all, and can only be got rid of by evaporation."

Need of Drainage.—There is very little land that is not too wet in rainy weather, and too dry in droughts; and drainage, as already explained, is a remedy against the last-mentioned evil as well as against the first. Notwithstanding all the drainage work of bygone years, the undrained wet land in Great Britain is probably not less than 25,000,000 acres. And it is too true that much of the drainage already done has been broken up by the abnormally wet seasons which have recently prevailed.

"It is lamentable," says the *Field*, "to note the effect of wet seasons on the permanency of drains, and this is especially true of those localities where the surface is flat, and where the land is affected by backwater, owing to floods. We have the misfortune to be intimately acquainted with such a district, where the land is above flood level, but where the drainage is often blocked for days, and sometimes weeks. The result is gradual blocking of the pipes from sediment. It is easy to understand how this occurs. The water backs up the drain and rises in the soil, which, having been disturbed in the making of the drains, is even more liable to be carried down with the retreating waters than the undisturbed land. Well, the flood ebbs often rapidly, the water sinks into the drain, and carries with it fine material, which is deposited. Varying according to the fineness of the soil, this process of blocking is a certain result of backwater; and we have known drains that were most carefully laid rendered useless in a few years from this cause alone. It usually happens that the soil in flat districts is more or less derived from drift materials, and the particles of such soil are often so fine that they will penetrate through the joints of the pipes, however carefully laid, and despite all precautions that can be taken. One of the lessons of recent years most absolutely demonstrated is the temporary nature of drainage works, quite upsetting all our calculations. There are of course special cases, and great differences as to the limit of durability. Thus, we know of drains in peaty soils which require dragging out, as it is called, every three or four years, in order to remove a deposit of oxide of iron, locally known as 'red rag'; and we find drains in upland districts where the fall is considerable, which appear as perfect now as when they were put in twenty years since. In low land, and especially when the soil is composed of fine materials, it often happens that 2-in. pipes will require to be re-laid after periods ranging from ten to twenty years; and, even if not entirely renewed, they are subject to constant repairs."

Causes of Wetness.—Soils may be wet and in want of drainage from various causes. The most frequent cause is rain-water falling directly upon the soil in too great quantity, and finding no sufficient escape through subjacent porous strata. Sometimes it is water of pressure, or "soke," as it is termed in the Fens, which is simply rain-water that has fallen upon neighbouring higher lands and filtrated downwards till it burst out in a diffused manner on the surface of porous soils at a lower level. In other cases, springs are the cause of wetness. Certain lands, also, are subject to be over-flowed and in need of drainage when rivers or tides rise sufficiently to bring water upon them.

Some lands are liable to suffer by one of these causes, and some by all of them; and to drain with advantage it is necessary to know how much of the surplus water is due to each of these causes.

Reference to geological formation must not, of course, be forgotten; for in carrying out the practical work of drainage very much of its success will be found to depend on a proper knowledge of the various strata, and their relative degrees of capacity for admitting or rejecting water. Some data on these points is given in the sixth chapter.

CHAPTER II.

METHODS OF UNDER-DRAINING.

Stone Drains.—Before drain pipes came into use, stones, gathered off the fields, were the common material of which drains were formed. Mr. Smith, of Deanston, even preferred stones to pipes, and he recommended that for this purpose the stones should be

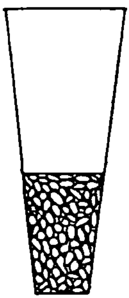


Fig. 1.

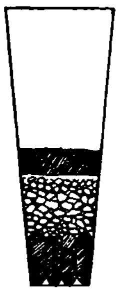


Fig. 2.

broken small enough to pass through a ring 2½ inches in diameter. From 9 inches to a foot in depth of stone was the quantity commonly put in. Some, however, filled the drains half-way with stones; others set a flat stone with its foot against one side and its top leaning against the opposite side; and others, again, adopted the different modes of construction shown in Figs. 1 to 6.

The use of stones as draining material is now, however, only justified where the land to be drained

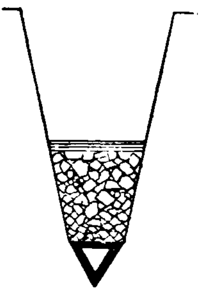


Fig. 3.

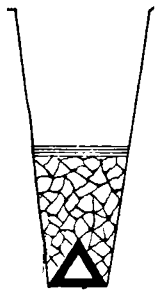


Fig. 4.

abounds in them, and no other use can be made of them. To make a good stone drain requires twice as much excavation, and involves twice as much labour, as is necessarily expended in tile-draining, and

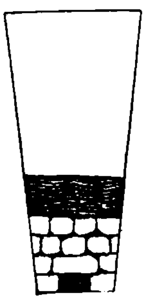


Fig. 5.

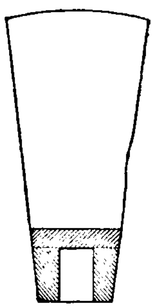


Fig. 6.

it is neither so effective nor so durable. In sandy and loose soils the stone channels are apt to get silted up by the water carrying fine particles of earth and sand down amongst the stones. Of course where it becomes a question of carrying stones upon the field to be drained, nobody would now think of putting in a single rod of stone drain.

Pole and Fagot Drains.—Prior to the introduction of drain tiles and pipes, various other kinds of material were used instead of stones, where the latter were not available. Sometimes a number of larch or other poles were put in to form a conduit, as in Fig. 7. Bush fagots were also employed for the same purpose, and even hedge cuttings and ropes of straw were at times used in the formation of covered drains.

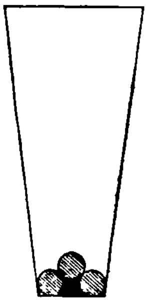


Fig. 7.

The Drain Pipe.—These are a few of the chief devices used in the early days of draining land. The invention of the drain pipe gave an immense stimulus to thorough draining, and thousands of acres of wet land, which previously had to be summer-fallowed, were laid sufficiently dry for turnip cultivation and sheep husbandry. A cart-load of pipes went a hundred times as far as a cart-load of stones; and as the pipes were of small diameter, comparatively little excavation was needed in putting them in.

The Horse-Shoe Tile.—The drain pipe itself has undergone various modifications. In its earliest form, the pipe or tile was made singly, and by hand. The


Fig. 8.


Fig. 9.


Fig. 10.


Fig. 11.

clay was rolled out, and then pressed over a block into the shape of a horse-shoe; and in using these horse-shoe tiles it was only deemed necessary to lay them on a hard bottom of clay. It was soon found, however, that this was not enough. The run of the water wore the bottom of the drain and softened the clay, till the tiles were either displaced altogether or would sink into the bottom, and make the drain useless. The next improvement was to make the horse-shoe tile with feet, as in Fig. 9, in order to prevent it sinking into the earth or clay on which it rested. An obvious improvement on this, however, was to set the horse-shoe tile upon a flat sole, a little wider than the tile itself, as in Fig. 10. When placed in position the possibility of the tile sinking into the earth was overcome, and, at the same time, a solid run was provided for the water which flowed through the drain.

The cylindrical Drain Pipe.—The sole and tile was in turn superseded by the machine-made pipe, in which the horse-shoe form, as in Fig. 11, was at first closely adhered to, but this has now been entirely superseded by the cylindrical pipe shown in Fig. 12, which possesses many advantages. It forms a complete conduit in itself, it is stronger than any other form of pipe, its extreme lightness makes it very easy of transport, and owing to its small diameter a less quantity of earth need be excavated in digging a drain for a cylindrical pipe, at a given depth, than for any other drain material.

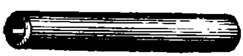


Fig. 12.

Pipe Collars.—Collars were for some time very generally used along with the cylindrical pipes, from an impression that they gave greater efficiency and permanency to the drain. The collars were short pieces of pipe just wide enough in the bore to admit the ends of the small pipes forming the drain, the object being to cover the junctions of these pipes, and to prevent them moving out of position after being laid. Fig. 13 shows two drain pipes connected by means of a collar. The collars have now very generally gone out of use, the prevailing opinion being that they are an unnecessary expense on all clean-cutting and firm-bottomed soils. If a solid foundation for the pipes is unattainable, as in deep peat-mosses or the

Fig. 13.

like, where a certain amount of subsidence is sure to take place after the drains are finished—or if the pipes are liable to silt up from the nature of the material in which they are laid—the use of collars may still be advisable at times, but in the great majority of cases they can very well and safely be dispensed with.

How Water enters the Pipes.—The question, "How does water enter a drain pipe when it is laid three or four feet deep in the soil?" is one often asked by beginners. From experiments which were carefully carried out by Mr. Josiah Parkes, in order to determine this point, it was found that under a pressure of 4 feet of soil, the absorbent power of various pipes formed of various clays was equal to the passing of about $\frac{1}{500}$th part of the quantity of water which enters the conduit through the crevice existing between each pair of pipes. By so much, therefore, the porous nature of the pipe material is useful; but, practically, this influence is so small that we may regard the whole of the water as entering at the joints. And not only does the bulk of the water enter the pipes at the joints, but the greater portion of it enters the drain pipes from below.

In all soils requiring drainage there exists a water-table or level of supersaturation, and in a well-drained soil this level corresponds with the level of the drain pipes. When rain falls on the surface the water finds its way downwards till it reaches this water-table. It then begins to rise, and if the drains are sufficiently active the pipes will carry off this rise of water as fast as it enters them from below. If the water rises above the level of supersaturation faster than the drain can take it off, then of course the pipes become completely swamped, as it were, and the water enters at every part of the joints. When the rain has ceased to fall, however, the continued action of the drain will soon suffice to again reduce the water of supersaturation to its proper level; water will even cease to flow from the drains until more rain falls, and then the same thing will go on as before, the height to which the free subjacent water rises being wholly dependent on the activity of the drain, and the sufficiency of the pipe to carry off the water from it in a given time.

That the water will be freely admitted to the pipes at the joints is easily shown. With 2-inch pipes, when laid as close end to end as possible, the opening between two of them is usually not less than $\frac{1}{10}$th of an inch on the whole circumference. This makes six-tenths of a square inch opening for the entrance of water at each joint. In the length of a drain between any two points, say 100 yards distance, with pipes 12 inches long, there will be 300 joints or openings, each six-tenths of a square inch in area, or a total area of 180 square inches for admitting water to the drain. The area of the outlet from a 2-inch pipe is, however, only about 3 inches, so that the inlet area is nearly sixty times greater than the outlet area.

Manufacture of Drain Pipes.—In all drainage works of any considerable extent, it will pay to make the pipes on the ground, if clay at all fitted for the purpose is obtainable. There is nothing more suitable than ordinary brick clay; and by employing machinery in their manufacture, drain pipes can now be produced very rapidly and cheaply.

There are various machines used in this work, but they all operate on the same principle. This consists in squeezing a continuous length of soft plastic clay through a ring-shaped orifice, the centre of which is occupied by a core or mandrel of the size of the hollow part of the pipe; another arrangement of the machine being to cut the pipes to the proper lengths as they pass through, and by means of a travelling table to carry them forward to be removed to the sheds, where they are dried previous to being burned in the kilns.

Some of the machines only work the clay after it has been prepared in a pug-mill; others consist of a pug-mill and pipe-maker combined. The uncombined machines cost from £20 upwards, according to size, and are capable of turning out, by man-power, from 200 2-inch pipes per hour, and upwards, or with one-horse power from 3,000 to 5,000 pipes per day. The pug-mill costs about £10 extra.

One of the best machines known to us is that made by the Boness' Foundry Company. Two sizes of this machine are sent out. They are of the combined kind, and prepare the clay and produce the pipes at one operation. Their peculiarity is in the screening compartment, where the clay is entirely freed from stones and all substances which would cause bad pipes to come from the dies, and from which all such refuse is ejected. The smaller one can be easily driven by 4-horse power, is worked by one man and three boys, and is capable of putting out of good clay 7,000 to 9,000 2-inch pipes daily. It costs, exclusive of driving power and belting, £70. The larger-sized one costs £100, can be driven by 5- or 6-horse power, is worked by two men and three boys, and turns out from 12,000 to 15,000 2-inch pipes daily.

A tilery, including a kiln capable of burning, say, 20,000 2-inch pipes, and drying sheds for the same, can be erected at a cost not exceeding £60; and with coal at 18*s*. per ton, the expense of manufacturing the pipes is from 15*s*. to 18*s*. per thousand. The quantity of coal used varies, as some clays require more burning than others; but on an average, perhaps, 2½ cwt. of coal will burn 1,000 2-inch pipes. The pipes are usually cut off the machine at 15 inches in length. In the processes of drying and burning, however, they shrink to 13 or 14 inches. (See Appendix, 10.)

Cost of Pipes.—The selling price of drain pipes varies greatly throughout the country, and in much the same ratio as does the price of coal. Appended are two price lists for the present year.

SELLING PRICES OF DRAIN PIPES OF VARIOUS SIZES AT THE KILN.

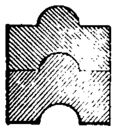
Inches diameter.	Gloucestershire.				Banffshire.			
	£	s.	d.		£	s.	d.	
2	1	5	0	per 1,000	1	9	0	per 1,000
2½	1	15	0	„	1	19	0	„
3	2	5	0	„	2	10	0	„
4	3	0	0	„	3	15	0	„
5	4	5	0	„	5	5	0	„
6	7	10	0	„	8	15	0	„
8		—			0	0	9	each
9		—			0	1	0	„
10		—			0	1	2	„
12		—			0	1	6	„
14		—			0	1	10	„

It is not too much to say that the pipes can be manufactured on the field at from one-half to one-third of the above cost.

Drain pipes, if well made and properly burnt, should be entirely free of warps and nodules; and if gently knocked, one against another, should give out a clear musical sound.

Peat Tiles.—Conduits formed of dried peat are sometimes used in draining peat-mosses and bogs, where there is always a superabundance of this material. These tiles are formed in half-sections, as shown in Figs. 14 and 15, and are cut with a spade similar to that represented in Fig. 16. They are fairly durable in soils of the class mentioned, and have certainly the merit of cheapness, as they are dried in the sun, the only cost being that of cutting and handling them.

Fig. 14.



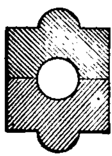


Fig. 15.

Fig. 16.

Wedge and Shoulder Drains.—Underground draining is also occasionally practised without the use of any drain material; and that in various ways. The most simple forms of these drains are what are known as the wedge-drain and the shoulder-drain. They are mere channels in the subsoil, formed by the bottoms of the drains being cut very narrow, and the upturned turf or grassy spit from the surface made to rest on the top of the wedge or shoulder, thus leaving a vacant space in the bottom of the drain, as shown in Figs. 17 and 18. These drains are less durable than the peat-tile drains, and like them are only adapted for old pasture lands, where they are entirely beyond the risk of disturbance by tillage operations.

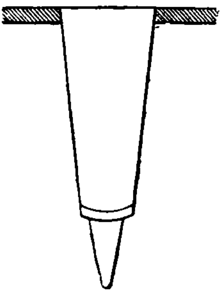


Fig. 17.

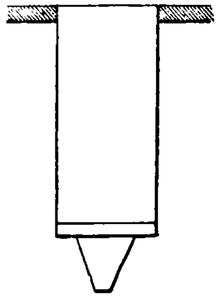


Fig. 18.

Draining Ploughs.—The mole-plough affords, perhaps, the cheapest means of under-draining without the use of any foreign material. The strong coulter of this plough carries on the back of its point a mole or plug, which leaves an open channel behind it, as it is drawn through the soil. The channels thus made in the land deliver into properly-constructed main drains with pipes of sufficient size. The implement can be made to work at any moderate depth, and either by horse or steam power; but it can only be used satisfactorily on homogeneous clays, or free loams, and is better suited to grass lands than to lands under tillage.

A recent correspondent of the *Agricultural Gazette*, who advocates mole-plough draining, may be quoted as to the cost of this method.

"Cost of Draining by Mole-plough.

"July 11th, 1881.

"Sir,—I am glad to find that the old-fashioned excellent practice of draining by mole-plough, with the use generally of steam-power instead of horses, has been revived with energy. As the following figures are facts, you may like to publish them. They represent the cost of draining a field (21 ac. 2 rd. 24 pl.) in Hoofield with mole-plough, and pipes in main drains:—

	£	s.	d.
Mole ploughing 1,328 rds. at 2½d. per rd. . . .	13	16	8
Cutting main drains	3	1	0
Pipes	5	2	6
Labour, coals, &c.	3	0	0
	£25	0	2

"The mole drains were made 8 yards apart. The cost per acre comes out at 23*s.* 1*d.* As the field may have been favourable for the work, the average may be put at 25*s.* an acre. This is certainly a very inexpensive method of laying the land perfectly dry to a depth quite sufficient for all the purposes of practical farming. The time has again come for economy. . . . Mole-plough draining will admit of at least 12-inch ploughing, &c.

"TOP SPIT."

Fowler's draining plough, which gained the Royal Agricultural Society's medal at Lincoln in 1854, where it was first worked by steam-power, may be used either as a mole-plough or to put in pipes. In the latter case it aims at making a complete pipe drain at a single operation, the drain pipes being strung on a rope, and rope and pipes together being drawn through the soil, behind the mole fixed on the point of the coulter. It may be worked to a depth of 3½ feet in suitable soils: and either by horse or steam power. It is said that the work done by this plough at the Lincoln meeting in 1854 is still giving entire satisfaction. Fig. 19 shows the improved form of Fowler's mole-plough.

But after all is said and done, draining by means of

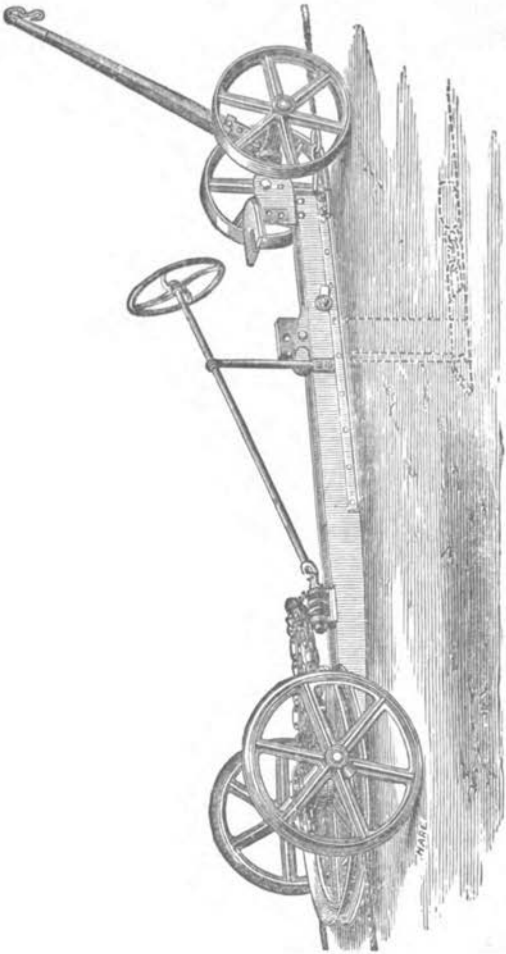


Fig. 19.

the mole-plough, even where it puts in no pipes, can only be practised to a very limited extent on the soils of this country.

Draining Machines.—The latest and perhaps the most ingenious implement of this kind was exhibited at the Derby Show in 1881, by Messrs. Robson and Herdman, the patentees. By the use of this machine, of which Fig. 20 is a side illustration, the complete process of land draining is automatically accomplished. The drain is excavated by a series of revolving buckets cutting to the required depth and fall; the drain pipes

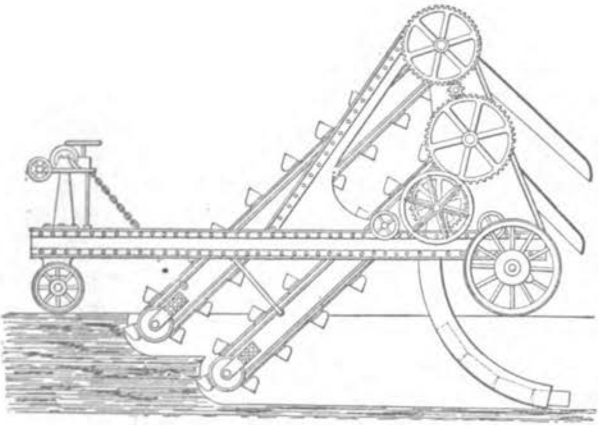


Fig. 20.

being laid by the arrangement shown in the drawing, and the earth returned to its position by suitable shoots, the subsoil being conveyed to the bottom of the drain. This machine is driven by a wire rope like a steam-plough or cultivator, and requires no more skilled attendance. Its cost (£390) appears to us simply prohibitive to its use; but it has never been fairly tried; and the inventors, we believe, have for some time past been engaged in working out some new idea in connection with the machine. Since 1881, the

Royal Agricultural Society has annually offered a gold medal for the best draining machine, but the medal is still unawarded. As Mr. Pidgeon, in his recent paper before the Society of Arts, has aptly pointed out, "several difficulties attend the problem of automatic pipe-laying. It is not easy to provide for a proper and equable fall; it is difficult to place the pipes accurately in contact end to end; and it is a question how turning at the headlands is to be accomplished."

CHAPTER III.

ARRANGEMENT OF DRAINS.

Determining the Outfall.—In proceeding to drain a field, the first thing to do is to decide on the point of outfall. Where the surface is undulating there is seldom any difficulty about this; but on low, flat lands it is often impossible to determine whether the ground has any fall or not until the levelling instrument is brought out. The number of outlets required will depend on the size of the field, and on the configuration of the land. If the land does not slope in more than one direction, and if the field is not of large extent, one outlet will probably be enough. Otherwise, however, it may happen that several outlets are required. If all the drains can be led in one direction, a single outlet may suffice for a field of 12 or 15 acres; in this area, however, there ought to be three or four main drains, all converging on one point. If the land has little inclination, there will be great advantage in concentrating the whole of the drainage on one outlet, and care should likewise be taken to run the main drains in straight lines towards the point of discharge. Where the inclination is greater, and the field to be drained is larger, a second or even a third outlet may be advisable, in order to shorten the lengths of the main drains.

Laying out the Main Drains.—The next step is to lay out the main drain or drains in the best direction for receiving the minor drains. This will always be along the lowest line of ascent from the point of outfall.

Arrangement of Minor Drains.—In the arrangement of the minor drains, the aim should be to lay the land dry with the smallest possible number of drains. Not a rod of drain should be cut that is not going to be beneficial. The causes which render the soil wet must first be considered. When these are known and understood, it will be easy to decide upon the best means of providing a remedy. But in this consideration the sectional strata of the district must be taken into account, as well as the contour of the surface, and the texture of the super and subsoils.

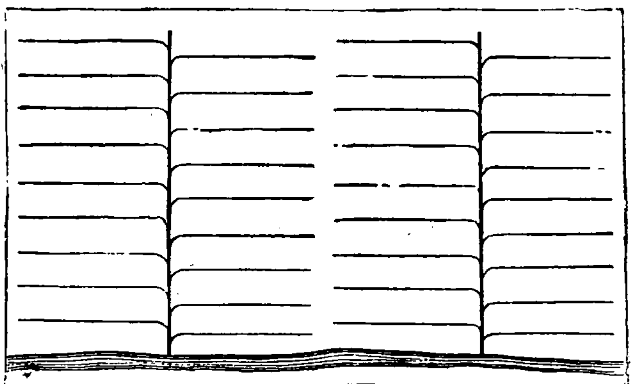


Fig. 21.

If the surface of the ground is level, and the structure of the soil uniform, the drains may be arranged at regular intervals apart (Fig. 21), with feeders at right angles to the mains, and the necessary slope must be gained by cutting (Fig. 22) deeper towards the outfall.

An undulating surface requires the mains to be placed at the lowest levels, and the minor drains

Fig. 22.

should run into them in the direction of the inclination of the ground (Fig. 23). When the surface inclines, there will be generally sufficient fall for dis-

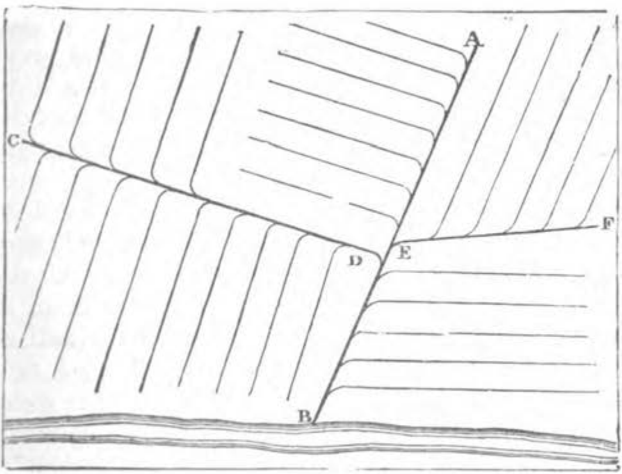


Fig. 23.

charge if the drains are cut throughout to a uniform depth (Fig. 24).

If the sectional strata consist of soils of various retentive powers, their relative positions, both in plan and in section, must be regarded in the arrangement of the drains. It is want of attention to this point which is the true source of so many fruitless attempts at successful land-drainage. Instead of following

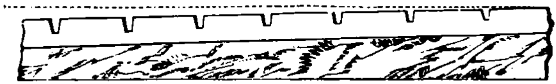


Fig. 24.

ready-made rules for fixing the proportionate depths and distances of drains in light and heavy soils, we must determine these points by reference to the thickness and order of the substrata, no less than by the character and texture of the supersoil.

Direction of Drains.—With the exception of the main drains, which must conform to the contour of the land and the point of outfall, all drains should be directed against the hill, or run in the direction of the greatest slope, and not made to cut it diagonally. By cutting across the slope a drain will undoubtedly intercept the water from the land above it, but it will do nothing towards relieving the wetness of the land below it. On the other hand, by cutting against the hill the land is not only drained on both sides, but a drain so applied will drain a soil deeper than the drain itself, as water lying above a given point will be drained to a depth the difference of the fall from the point in question in a direction up the level of the drain. Further, it is obvious that a drain laid on across the slope of greatest inclination, or diagonally to it, will not empty itself so soon as one which follows the direct line of greatest inclination. Where the flow is sluggish it even happens at times, with the drains laid on across the slope, that some of the water finds its way through the sides of the drains before it reaches the point of outlet, and thus, instead of serving to drain, helps to keep the land below it wet. So that while a drain cut down the slope will receive the water from the sides, the top, and the bottom, a drain across the slope will only receive the water at the upper side of it.

Yet there can be no hard or fast rule in this. An exception is generally made in draining old pastures lying in high ridges, that have, perhaps, for generations determined the direction of the water, when these run obliquely to the ascent. This is entirely to ignore the fact that the forming of land into ridges and furrows was the original mode of surface drainage, and that if under-drainage is properly carried out, there can be no need of surface furrows. Unfortunately, a large portion of the arable surface of England still partakes of the ridge and furrow form; even on strong clay arable lands, however, the ridges and furrows are mostly disregarded, particularly if they are of irregular width.

There is sound practice as well as sound theory indicated in Mr. Bailey Denton's lines:

> "When land is drained no furrows keep,
> But lay it flat and plough it deep."

"I have seen many clay-land farms that have not been rendered dry by draining," says Mr. Denton, "because in order to develop the draining those lands require an after treatment,"—deep cultivation and laying them flat where they have been in ridges—"which they have not received. There are many farmers who believe that if their land is drained they have nothing to do to help the drains. There is no greater mistake. Deep cultivation on land moderately drained very materially assists to rid the land of water. The more you stir the soil the more you assist in drainage, and the fewer drains you require." On under-drained pasture land nature performs this work for herself. Every shower that falls makes both surface and subsoil more porous, carrying air and rain together down to the drains.

Again, in any case it will be useless to drain against the dip of the strata. It may also sometimes occur that the existence of a spring between two parallel drains may necessitate its being led into one of them by means of a side drain, although, if the parallel drains are not over distant, the water in such cases will generally find its own way. The extreme mobility of water, and its tendency to force its way along by its own gravity, wherever the pores of the soil are open to the atmosphere, is well known to every one. If a pipe drain be laid down in a dry soil, the channel is immediately filled with air, but when rain falls, and the soil becomes saturated to the level of the drain, the water in the soil, by reason of its greater weight, occupies the place of the air in the drain. The water which is nearest to the drain is first drawn off, then that next to it immediately takes the empty place, and so on and on, the last pushing and driving the first beyond any limits which we can affix to it.

Inclination.—The rate of fall which can be obtained according to the surface levels of the district is not only important as regards the discharge of the water from the pipes, but it will occasionally have an influence in regulating the depth of the drains. Theoretically, water will flow if there be but the smallest possible deviation from a horizontal line; but in practice this is not sufficient, for it implies a perfectly smooth and level bed, a condition which does not exactly exist in land drains. A fall of one in two hundred will afford good drainage, but in the stiffer class of soils an inclination of one, two, three, or more in a hundred is preferable, if obtainable. The water should not pass too quickly through the soil before it has time to deposit its nutritive ingredients; but neither should it be allowed to stagnate, as it will do if the drains are deeper than it can readily permeate, or if the fall is insufficient to induce a free discharge. On very porous soils a smaller inclination will suffice than is necessary with a soil where percolation is not so rapid. When the drains are sufficiently active they will not allow the water to stand on the surface longer than a few hours after heavy rains. Stone drains require more fall than tile drains, as the friction to be overcome by the water is greater in the former.

Length of Drains.—Long drains, as a rule, are more effective than short ones. This is seen to perfection on the wet level lands which are sometimes met with, where it is very difficult to get drains to run, unless such a quantity of water is collected in them as forces a current by its own gravity. In such places long drains are an advantage, as the increased quantity of water which they collect causes a constant run, which keeps them clear and free of obstructions. But it is one of those matters of detail which must be decided according to the circumstances of the case. Some advise that the length of a drain should not exceed 300 yards, and that where there are springs in its course it should not exceed 200 yards. Main drains, undoubtedly, should be made shorter rather than longer, if there is any choice, because the longer the main, generally, the greater the number of feeders led into it; and to lead the drainage of a large tract of wet land all into one main drain is very often to endanger the safety of the whole, if an obstruction should occur in the main, or it should prove inadequate to carry off the water.

CHAPTER IV.

DEPTH AND FREQUENCY OF DRAINS.

Depth of Drains.—"The circumstances affecting the proper depth and distance of drains are very numerous. Deep drains are longer in beginning to flow, but if the soil is porous, they will carry off the surface water after heavy rains sooner than shallow drains. They also drain a greater bulk of the soil, and allow the water time to deposit the particles of mould and manure which it carries in from the surface of the ground.

"On an open soil which the water penetrates freely, the action of the drains will extend to a considerable distance, if the depth is made proportionate; but on stiff, compact soils, percolation will be greatly hindered, and therefore the action of the drains will extend a less distance than on free and open ground, where the water finds a ready escape. No amount of depth will compensate for excessive distance on a compact soil, because the material either resists the passage of the water altogether, or the removal is so slow that the drainage is worthless. It is also evident that drains may be laid too deep, for the same causes which hinder the lateral course of the water are obstructive to its vertical descent in the soil.

"If the upper bed is retentive, and of such depth that the drains cannot be cut completely through it, the best system to adopt will be shallow drains at close intervals; and, on the contrary, a pervious material should have deeper drains at wider intervals.

"If a comparatively thin bed of clay rests upon a porous substratum, the drains should be cut into the latter, or through it, according to its depth; and they must in any case be laid at small intervals.

"When the case occurs, as it sometimes does, that a free supersoil about three feet in depth overlies a comparatively thin bed of clay, it is often advisable to limit the depth of the drains to that of the porous bed. By penetrating the clay the land would be better drained, but in doing so there is a risk of exposing springs, if they exist below the clay.

"The requirements of vegetation must also be considered in determining the proper depths of drains. The depth to which the rootlets of the plants penetrate may afford some indication of how far the free subjacent water should be retained below the surface. It is often alleged that in dry summers, grass land especially is subject to great injury, owing to the depth of the drains below the rootlets being beyond the capillary power of the soil. There is, however, strong evidence that the roots of all our cultivated crops, grasses included, do descend and appropriate the soil to as great a depth as they are permitted; and it should not be forgotten that every inch of additional drainage, or every inch of additional depth cultivated, is a gain of 100 tons of active soil per acre." *

In reference to this part of our subject, Mr. J. Bailey Denton says:—

"I published recently some very curious illustrations

* "Soil of the Farm." By John Scott and J. C. Morton.

of the dislike plants exhibit for stagnant water in the soil. They afforded proof that directly the roots reach the standing-water level, they ceased to penetrate farther. I have evidence now before me, that the roots of the wheat plant, the mangold wurzel, the cabbage, and the white turnip, frequently descend into the soil to the depth of 3 feet. I have myself traced the roots of wheat 9 feet deep. I have discovered the roots of perennial grasses in drains 4 feet deep; and I may refer to Mr. Mercer, of Newton, in Lancashire, who has traced the root of rye-grass running for many feet along a small pipe drain, after descending 4 feet through the soil. Mr. Hetley, of Orton, assures me that he discovered the roots of mangolds in a recently-made drain 5 feet deep; and the late Sir John Conroy had many newly-made drains, 4 feet deep, stopped by the roots of the same plant."

For purposes of cultivation, the drains should never be laid at a less depth than 3 feet from the surface of the ground. Even with steam ploughing and subsoiling, the depth of, say, a 2½ foot drain will not ordinarily be reached; but it is evident that drains may be completely destroyed by the operations of tillage, without the drain pipes being actually touched or disturbed. In most soils, shallow drains become rapidly choked by being filled up with fine particles washed down through the openings occasioned by tillage and other surface influences. This is especially the case on fine sands and alluvial deposits, where the silt rapidly penetrates to the depth of a shallow drain. Deep drains for these reasons are more secure and remain longer efficient.

Solar influence, also, is not without its effect on the proper depth of drains. Clay lands with a southern slope will require drains at a greater depth than lands with a northern aspect: and, likewise, lands of a southern latitude than those of a northern.

Lastly, as has been already seen, the rate of fall obtainable according to the surface levels of the district has its effect in determining the depth of drains. Where the outfall is deficient, as in the case of most low-lying lands, the top ends of the drains can rarely be made so deep as the lower ends; and the same rule has to be observed wherever the surface is so flat that there is no other means of giving the drains a proper fall.

Recent Practice in Draining.—Whatever may be said in favour of deep drains as against shallower ones, there can be little doubt that closer draining is now being practised than was formerly believed necessary by the advocates of deep drains, and the inference is that they are at the same time draining shallower. On this head some curious and important revelations were made by Mr. Bailey Denton in his evidence before the Royal Agricultural Commission. Some of Mr. Denton's answers to questions relating to drainage are of so much consequence that I give them in full here.

At page 169 of Minutes of Evidence, he is reported to have said: "There is no doubt but that the rules prescribed by the Enclosure Commissioners, with regard to the necessary depth of parallel drains in clay soil, and the distance between them, have not been fully justified with free soils and irregular surfaces.

"It is found that no rule whatever will apply with clay and homogeneous soils. . . . The generally adopted parallel system, based on the theory propounded by the late Mr. Josiah Parkes, that the deeper the drains the wider may be the intervals between them, does not hold its ground. When obliged, by the rules laid down by the Enclosure Commissioners, to conform to the depth of four feet, landowners were encouraged by the Parkes' theory to lessen the frequency of the drains in order to keep down the cost. The result was that the distance was extended beyond the limit of reciprocal action, and it has now been found that the full effect aimed at has not been secured. Instead, however, of attributing unsatisfactory results to the real cause—*i.e.* excessive distance between the drains—they have been attributed to excessive depths, and the principle of deep drainage, which is sound in itself, has thereby lost ground. With the cost of manual labour increasing in this country, without the returns of farming keeping pace with the advance, it has become positively necessary, if clay lands are to be drained at all, that a compromise should take place. A width of 24 ft. is taking the place of 36 ft., and a minimum depth of 3 ft. that of the universal 4 ft." Again, at page 223, he goes on to say: "I certainly am bound to confess if I had some drainage that I have executed to do again, I should drain it differently; but I do not take to myself any blame for that. It was a law, a rule of the Enclosure Commissioners, to drain 4 ft. and nothing under. That required a certain width, a certain distance between the drains, to bring the cost to a reasonable amount; and land was drained 30, 33, and 36 ft. apart, which, if I were to drain again, I should not certainly exceed 27 ft. in interval; 21, and 24, and 27 ft. would be the distances I would now adopt in place of 30, 33, and 36 ft. The Commissioners are now, I believe, acting on that view, and they no longer require 4 ft., except in cases where their inspector considers 4 ft. the best depth to drain."

Distance between Drains.—Practice seems to say that the distance between drains on strong clays may be from four to six times the depth, on strong loams six to eight times the depth, and on light soils eight to ten times the depth.

It is easy to discover the origin of the rules for distances by looking back to that of parallel drainage. Prior to the practice of under-drainage, strong and wet lands were rendered capable of tillage by being ploughed up in the waving shape termed "ridge and furrow," the bottom of the furrow forming the drain for the ridge. In consequence, however, of the crops perishing in and by the sides of the furrows, the water was drawn off from them by having shallower drains below each, and kept open by straw or brushwood. This was termed furrow, or thorough draining. "It is thus that the distances of the furrows from each other indicate the distances of the drains in any particular district. And the distances now most commonly in use, in different districts and on different sorts of soils, have all reference to a width of ridges that either formerly was, or now is, in use in those districts. Throughout the country the statements of the number of feet from drain to drain is, in almost every instance, when reduced to inches, divisible by 18, that being the width of ground moved at a single bout of ordinary ploughing." *

Gradual Drainage of Boggy Land.—The perfect drainage of deep and wet boggy land is a gradual process, requiring some time to reach the proper depth. The drains in this case should be cut at first only as deep as the sides will stand, and gradually deepened as the land subsides, taking care to keep the open trenches

* Mr. Spooner.

well cleared out. When the land has become sufficiently consolidated, the usual pipe drains may be put in, but they should be laid rather beyond the depth which would be thought necessary in a firmer soil of the same nature. If the moss will not carry the ordinary pipes, it will be advantageous to use collars with them, in order to prevent their displacement.

Draining Peat Mosses.—Peat or vegetable soils possess, in a very strong degree, the power of capillary attraction, and their porosity is also so great that if one portion of the peat be made dry the moisture contained in the other parts will rapidly distribute itself through it. In order, then, to drain a peat soil thoroughly, and to counteract the effects of capillarity, the drains must be laid deep, but they need not be so frequent as in less porous soils. A single ditch dug down to the bottom of the peat, or as near it as possible, will draw off a considerable quantity of the moisture, not merely from its immediate neighbourhood, but from the whole moss. Where the peat is of no great depth, and recumbent on a clay bottom, the drain should, if the outfall will admit of it, be cut through the peat into the clay, after the manner shown in Fig. 25. If this plan can be adopted it will have the effect not only of depriving the peat more completely of its moisture, but it has an additional advantage, inasmuch as the sides of the drain will stand better while it has to remain open.

Auger Holes.—Where springs which are fed from a higher level lie immediately below a clay substratum which exceeds the practicable depth of the drains, recourse may be had to tapping, by means of an auger hole, or vertical bore, in order to open a communication to the drains, by which the contents of the springs will be carried off.

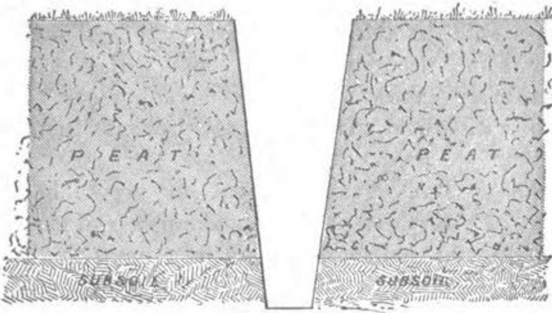


Fig. 25.

"Marshes, and even lakes, which occupy a bowl-shaped cavity, rendering drainage by the ordinary means impracticable, have been completely drained by boring through the impenetrable surface layer when it is not thick, and rests upon a porous substratum of sufficient depth to bear the water and carry it off from the surface. But this method must not be tried without due attention to the disposition of the sectional strata of the district, for if the porous soil is surcharged with water from a higher level the proposed cure will prove an aggravation of the existing evil. In that case the object may be attained by cutting a deep ditch or canal through the bank, on a level with the bottom of the lake." *

Swallow-holes and absorbing Wells.—There are extensive areas of land resting on a chalk subsoil where drainage, both natural and artificial, is carried on by means of what are known as "swallow-holes," or "dumb-wells." In all chalk formations "there are

* "Soil of the Farm."

large sand and gravel pockets, like inverted sugar cones, the origin of which is this. The rain water falls on the surface, and pure water being a powerful solvent of lime, dissolves it and filters down and is carried away in the springs. That goes on, and the gravel follows it down, and so we have these inverted cone and pipe deposits in the chalk in some instances of great depth, simply showing the solvent action of the water on the lime." In many districts where a clay soil overlies the chalk, by sinking a "swallow-hole" through the clay, down to the chalk, the drainage of the land is completely absorbed.

The best method of getting rid of springs will be suggested by surrounding circumstances. In few cases will it be necessary to do more than tap the spring and carry it off to the nearest drain or other outlet.

CHAPTER V.

THE DIGGING OF DRAINS.

Best Form of Drain.—In digging a drain it should be cut as narrow as possible. If the bottom is just wide enough to receive the pipes (Fig. 26) it is all that is necessary; moreover, when the pipes are thus accurately fitted in, the drain is more efficient, and, at the same time, more cheaply cut. Every spadeful of earth excavated beyond what is actually needful, in order to admit of the pipes being properly laid, is labour and money wasted.

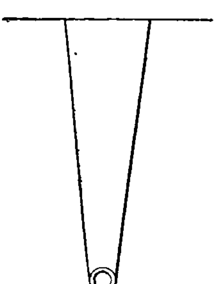


Fig. 26.

This accurate fitting in of the pipes is, with skill on the part of the workman, rendered quite practicable in the case of all soils tolerably free from stones, by the excellence of the draining tools that are now obtainable.

Marking out the Drain.—The drain should be staked and lined, and then edged, or marked out, on both sides by means of a common garden spade, such as shown in Fig. 27, which is also the best tool for removing the turf, or top spit. The middle and bottom spits are taken out by long tapering spades, similar to the Birmingham spades illustrated in Figs. 28, 29, and

30, each spade being followed by a corresponding-sized scoop to take up the loose earth. The scoops used are represented in Figs. 31, 32, and 33.

Digging.—In digging a 3-foot drain, after taking

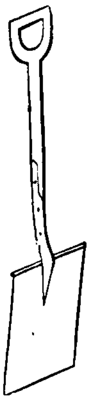



Fig. 27. Fig. 28. Fig. 29. Fig. 30.

off the top spit with the garden spade, only two of the long spades, as a rule, are used—one to take out the middle spit, another to take out the bottom one. In digging a 4-foot drain, however, there are generally three spits besides the top one, and in this case all the three Birmingham spades, or others, would in turn be called into use. The one which cuts the last spit (Fig. 30) is called the bottoming tool, and its introduction has effected a considerable saving in the cost of cutting drains.

Where the subsoil is hard, the pick has often to be used. In some soils, indeed, the pick has to be employed in loosening every spadeful of earth before it can be thrown out. In such cases the long

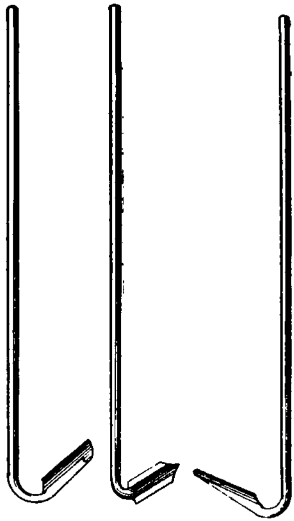


Fig. 31. Fig. 32. Fig. 33.

tapering spades are comparatively useless. Where picking is required, the drainer must stand in the bottom of the drain to get at his work, and this occasions a much wider cutting than in soft clays where the workman can stand above his work and send his long spade down 12 or even 18 inches lower. The cost of cutting drains in these hard or stony soils is of course considerably greater, both on account of the picking which is necessary, and by reason of the greater quantity of earth which has to be excavated. The picks, or pick-axes as they are sometimes termed, are usually made with a point at one end and a chisel or axe at the other (see Figs. 34, 35).

The digging should commence at the lower end, and proceed up the hill, thus allowing the water to run off and leave the drain dry digging. It is most

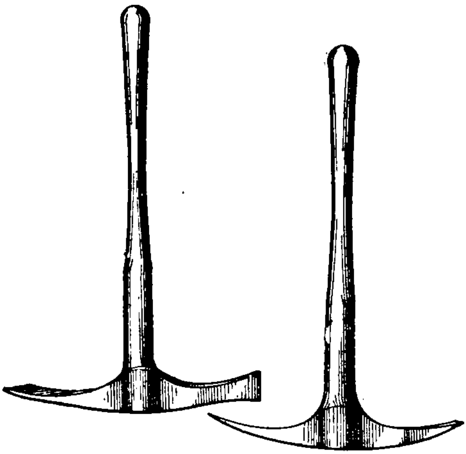


Fig. 34. Fig. 35.

important that the bottoms of the drains should be properly graduated. To ascertain this, various tests may be applied. One is to pour water into the drain at the upper end and mark any interruptions in its flow. In other cases the levelling staff is used. But for irregular surfaces the use of "boning rods" is to be recommended, though these serve only to show the evenness of the drain bottom, and not the amount of fall. Three "boning rods" are the fewest that can be used. Two of them are staves about 4 to 5 feet long, with cross-heads, and one of these is set up perpendicularly at each end of the drain. The third staff is considerably longer, with a movable cross-head, and is set up at the same height as the others; and when held perpendicularly and moved up and down the drain between the two end staves it shows to a person looking across the cross-heads where the bottom of the drain is faulty.

Where the drains are deep and the sides apt to fall in, the earth should be first taken out the whole length of the drain and within a foot or so of the intended depth ; then the bottom spit can be taken out by one or more men according to the length of the drain, and the bottoming and laying of the pipes all completed in one day.

The Upton Draining Tool.—This implement, although it has certain advantages over the ordinary flat and curved spades, and has had its merits well described by Mr. Milward, has been much neglected. For deep draining in clay soils its use is certainly to be recommended, both for the ease with which a great depth is obtained at one thrust, and the small quantity of earth required to be excavated and filled in.

In using the flat or straight-edged spade, it will be found that the drainer inserts it thrice into the ground before he can remove the spit of earth, as is shown in Fig. 36. A thrust on each side separates the spit laterally, and the last thrust detaches it at the bottom. Great force would be required to tear the spit of earth from its place without previously detaching it at the sides. The curved tool is intended to obviate this necessity, but is not found to do so effectually in practice ; the spit of earth, as is seen in Fig. 37, is still not completely separated at the sides, and must either be torn away or detached by side thrusts.

The inventor of the Upton draining tool thought that the resistance thus offered to an ordinary draining spade could be very materially diminished if the spit could be entirely detached as the tool descended. He decided, therefore, on a tool with two sides united together at the back, so that its section would be like the letter V. Considering, also, that if spits in the form of equilateral prisms could be taken out, the drain would be most readily excavated, the angle between the sides was fixed at 60°—the angle of an equilateral triangle.

In using this tool, which is illustrated in Fig. 38, the

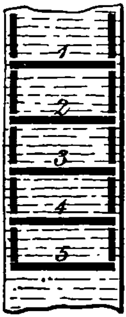


Fig. 36.

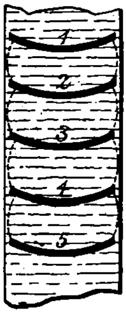


Fig. 37.

right side must be kept flat against the right side of the drain; and when this spit is withdrawn and the next thrust is made, the left side of the tool must be kept against the left side of the drain, and so on alternately.

Fig. 39 shows the manner of using the tool. The black line V shows the mark made on the surface by thrusting the tool into the ground; *h* indicates the position of the handle; the spits of earth marked out on the surface are numbered 1, 2, 3, 4, and 5, in the order in which they are removed. *A* is a piece of iron fixed as a rest for the foot in driving the tool into the ground.

In deep clay soils the success of this tool is very great. It is made of different sizes. The first and largest takes out a depth of about 18 inches; and longer but narrower tools are used for completing the dain to the required depth, the width at the bottom being only 3 or 4 inches. Some dexterity is required in keeping the tool properly along the side of the drain, also in withdrawing the spit which has been cut out; but the latter difficulty is easily overcome by inclining the spade a little instead of driving it straight down.

Fig. 38.

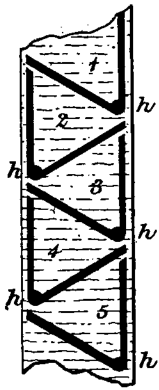


Fig. 39.

Opening Drains with the Plough.—The drain plough is sometimes used as an adjunct in opening drains; but it is more often heard of than seen. Mr. Wilson, however, has recorded his experience in the use of this implement, and the results may be given. The price of the plough, in full working order, he puts at £20; and the cost of using it for one day (including horses, men, and wear and tear, and interest on capital) at £3 12*s*. In one day's work the plough opened 1,800 lineal rods of drain 20 inches deep, 16 inches wide at the top, and 8 inches wide at the bottom, thus leaving room for men to follow with draining spades to the required depth. The cost of cutting is thus less than a halfpenny per lineal rod of drain; or, 2,333 cubic yards of earth are cut and thrown out at a cost of

4-10ths of a penny per cubic yard, which shows a considerable saving when compared with manual labour.

Quantity of Earth moved.—Mr. Denton, in his evidence before the Royal Agricultural Commission, declares that "The character of earthworks has not improved at all in the thirty years during which I have been connected with the General Land Drainage and Improvement Company. I find that with an expert hand and good tools, a 4-foot drain may be cut with a 13- or 14-inch opening at the surface, tapering down to 4 inches at the bottom, and that then the quantity of earth removed is reduced to a minimum; nevertheless, the same quantity of soil is still thrown out that used to be thirty years ago—double the amount that is necessary." This does not say much for our fine old English navvy!

The item of labour can easily be determined by referring it to the standard of the value of moving a solid yard of earth of any one description of hardness or tenacity.

Table of Earth-work.—The following table gives the number of cubic yards of earth in each rod of drains of various dimensions, and will show the economy of guarding against needless width in digging drains.

Depth of Drain.	Mean Width of Drains.											
	in. 7	in. 8	in. 9	in. 10	in. 11	in. 12	in. 13	in. 14	in. 15	in. 16	in. 17	in. 18
Feet.	Cubic Yards.											
2½	0·89	1·02	1·14	1·27	1·40	1·53	1·65	1·78	1·91	2·04	2·16	2·29
3	1·07	1·22	1·37	1·53	1·68	1·83	1·98	2·14	2·29	2·24	2·60	2·75
3½	1·25	1·42	1·60	1·78	1·96	2·14	2·32	2·49	2·67	2·85	3·03	3·21
4	1·42	1·63	1·83	2·04	2·24	2·44	2·65	2·85	3·05	3·26	3·46	3·66
5	1·78	2·03	2·29	2·54	2·80	3·05	3·31	3·56	3·82	4·07	4·33	4·58

Thus, if a 4-foot drain be cut 14 inches wide at top and 4 inches at bottom, the mean width will be 9 inches, and the quantity of earth excavated in cutting each rod will be 1·83 cubic yard; but if the same drain be cut 18 inches at top and 8 inches at bottom, the mean width will be 13 inches, and 2·65 cubic yards of earth will have to be removed in cutting each rod; so that if the digging of the drain costs 2*d.* per cubic yard of earth moved, the narrow drain will cost $3\frac{2}{3}$*d.* per rod, and the other nearly $5\frac{1}{3}$*d.* per rod, showing the cost to be almost doubled quite unnecessarily.

The same table will be found useful in helping to fix the relative prices of deep and shallow drains; but it must be recollected that the deeper drains will be increased in cost not only by reason of the greater quantity of earth which has to be moved, but also because of the increased labour of lifting the earth to the surface from a greater depth.

Supervision and Maintenance of Drainage Works.—As land drainage, if well done, is done for a lifetime, it is a work which should be closely and carefully superintended. If the pipes are once covered all defects are hidden until the drains are tested and found wanting—hence the importance of supervising the work as it proceeds. But the need of supervision does not end here. Mr. Bailey Denton rightly says that much of the discredit and unpopularity attending drainage at the present day, is due to the want of proper supervision *after the work is executed* to see that the pipes and outfalls are kept clear. And yet the charge of 2*d.* per acre in several instances has been found sufficient to secure the proper maintenance of outfalls.

Plans of Field Drains.—"Having perfected the work," says Mr. Denton, "one thing still remains to be done. A plan or record of the lands drained and the position of the drains is necessary, and in order that such a record may be preserved for future generations it is desirable that a national office connected with the Tithe and Enclosure Commissions should be set apart for the purpose. . . . . The cost of planning the drains after execution need not exceed 6*d.* or 9*d.* per acre where a map of the lands already exists, and after we have spent £5 per acre in draining, does it not appear the very height of folly not to preserve a record of so expensive an object at a cost of 6*d.* per acre?"

CHAPTER VI.

SIZE OF DRAIN PIPES.

Influence of Length of Drain on Size of Pipe.—As regards the size of drain pipes it is very important that the capacity should be of ample proportion to the quantity of water they have to discharge. When the drains are of great length pipes of different diameter should be used, the larger-sized ones being placed at the end of discharge into the main drains. It is only in this way that the size of the pipe in every part of the drain can be proportioned to the greatest quantity of water which will flow through it. For example, if a drain is 500 yards long, and the distance between the drains is 8 yards, the pipe at the mouth must be able to discharge all the water drained from the 4,000 square yards of land, while at the middle or half-length of the drain the pipe will only require to convey the water from 2,000 square yards.

Level Ground requires larger Pipes than where the Inclination is greater.—It often occurs, too, that the lower part of the field is more level than the upper part, a circumstance which demands a larger-sized pipe, because the velocity is less while the discharge at this part of the drain is generally greater. Again, on lands nearly level, the diameter will require to be greater than on those of considerable inclination.

These are points of far greater consequence than is often imagined, for in very many cases the same size of pipe is used for all lengths of drains.

Construction of Pipe influences discharge.—The smaller the pipe and the less the amount of water to be discharged, the greater ought to be the care in having pipes of perfect construction. In some trials with drain pipes it was found that with pipes of the same diameter, exactitude of form was of more importance than smoothness of surface, that glass pipes of a wavy surface discharged less water than clay pipes of exact form. By passing pipes of common red clay under a second pressure, obtained by a machine at an extra expense of 1*s*. 6*d*. the 1,000, whilst the pipe was half dry, very superior exactitude of form was obtained; with the same diameter, an increased discharge of nearly one-fourth was effected in the same.

Influence of Rainfall.—Great caution is needed in coming to conclusions as to the amount of discharge with a given rainfall. In some cases the drains begin to flow nearly as soon as the rain begins to fall, and cease to run immediately on its becoming fair, whereas in other cases the soil will absorb several hours' or even days' rainfall, thus protracting the flow at the commencement, but lengthening it out for several days, it may be, after the weather has become dry.

Distribution of Rainfall.—The amount of water which falls on any field is easily ascertainable from the rainfall statistics of the district, and it may be calculated in gallons of quantity, in cubic feet of measure, or tons in weight, taking 101 tons per acre for every inch in depth of rain. For example, the average annual rainfall of England and Wales is 32 inches, which represents a mean quantity of 723,904 gallons, or 116,114 cubic feet, or 3,232 tons per acre. But in conducting a work of land drainage, this knowledge of the average annual rainfall is of comparatively little use to us, until we know also the greatest annual rainfall, and the greatest rainfall in any one day during the year. A rainfall of 32 inches per annum, if spread equally over a twelvemonth, gives 1,983 gallons per acre per day; but the rainfall is never thus evenly distributed, and if the size of drain pipes were to be determined on a calculation of this kind, the mistake would soon become apparent. In many cases more rain falls in a single day than will fall for months afterwards. The distribution of rainfall in days, months, and years is therefore quite as important as the average annual amount, and can only be ascertained by careful observation, extending over a long period of time.

The following data, by Mr. Philips, as to the most rapid rainfall in Britain, illustrates very forcibly how the greatest rate of rainfall diminishes according as the period for which it is reckoned is increased.

Period.	Total Depth of Rainfall in Inches.	Rate of Rainfall. Inches per Hour.
1 hour	1	1·0
4 hours	2	0·5
24 hours	5	0·2 nearly

Augmented Rainfall of Districts.—It must also be remembered that the water in the soil may be augmented from two other sources, viz. from springs which burst up from below, and from moisture which finds its way from higher porous strata on to lower ground in a diffused condition. The latter is distinctively known amongst drainage engineers as *water of pressure.* The amount of drainage which may be needed to counteract these two causes of wetness can only be decided on inspection. The rainfall is a determinate quantity and can be measured, but no rules whatever can be formulated as to the size of pipes necessary to carry off the overflow or outbursts of springs and of water of pressure.

Amount of Rainfall evaporated.—Taking, however, all these three causes of wetness into consideration, we have next to estimate the amount of water thrown off by evaporation from the surface of soils, crops of all kinds and pastures, and from trees. Evaporation goes on at all temperatures, and in a clear atmosphere the higher the temperature the greater the evaporation; but it is not entirely dependent on temperature; dry parching winds also accelerate it. Trees are the most active evaporators; they strike their roots into the ground, and bring up the deep waters, which are given off by every leaf in the form of vapour. Trees, not in a thick wood, have been found to throw off three times the weight of rainfall over the area they cover.

In a series of experiments, Mr. Williams, of Worcester, found the evaporating properties of the subjoined trees and bushes as follows. He weighed successively 100 parts of the leaves of the oak, elm, horse-chestnut, poplar, ash, hawthorn, holly, and Scotch fir; having secured the end of the stem of each from evaporation by means of gum, he subjected them for twelve hours to a July sun, and found them to lose weight by evaporation as follows:—

		Loss.	
Ulmus Campestris	Elm	1-3rd of its weight	(Exotic).
Populus	Poplar	1-4th ,,	(Exotic).
Hippocastanea	Horse Chestnut	1-5th ,,	(Exotic).
Cratægus Oxyacantha	Hawthorn	1-6th ,,	(Exotic).
Quercus Robur	Oak	1-15th ,,	(Indigenous).
Ilex	Holly	1-25th ,,	(Indigenous).
Pinus Sylvestris	Scotch Fir	1-50th ,,	(Indigenous).

Pasturage is perhaps only second in importance to trees, and, in this respect, corn crops may fairly be reckoned as long grass. But from plants of all kinds, from the bare soil, and from pools and streams of water, evaporation is continually going on.

The mean evaporation, in this climate, during three years' observations, has been found to be very considerable, as will be gathered from the following tabular statement of facts:—*

From the surface of	Yearly Evaporation in Inches.	Comparative Evaporating Power, taking Water as Unity.
Water . . .	18·79	1·00
Ordinary soil .	15·12	0·80
Peat	13·62	0·72
Silt	14·03	0·74
Clay soil . .	13·58	0·72
Long grass .	48·16	2·56
Short grass .	23·50	1·25
Red clover .	53 44	2·83
White clover .	31·15	1·65

Amount of Rainfall absorbed.—In addition to the amount of water actually evaporated from the soil and from plants, &c., the quantity absorbed and retained by vegetation is very considerable. For example, a crop of turnips contains 90 per cent. of water, fresh meadow

* Schubler found the evaporation from soils of various characters to be as follows:—

	Evaporation from 100 parts of absorbed water at 65¼° Fahr. in 4 hours.
Silicious sand	88·4 parts
Calcareous sand	75 9 „
Sandy clay	52·0 „
Loamy clay	45·7 „
Pure grey clay	31·9 „
Humus	20·5 „
Garden mould	24·3 „

grass 72 per cent., and even dry hay as much as 15 per cent. of water. On the whole, therefore, we may assume that not more than from ¼th to ⅓rd of the rain which falls will be left for percolation and drainage. With a rainfall of 32 inches, that still leaves for percolation and drainage from 808 to 1,076 tons per acre per annum.

The power of soils to absorb and retain water is extremely various;* but this, though important as

* According to Dr. Anderson, the late able chemist to the Highland and Agricultural Society of Scotland, ordinary arable soil never retains in this way more than half its weight of water, and the lighter and more sandy soils much less; while decomposing vegetable matter (pure humus) is capable of holding nearly four times that quantity, or about twice its own weight. Peat possesses this property to a still larger extent; a specimen of good quality, taken from the surface of a moss, has been found to retain six times its weight, or twelve times as much as an ordinary arable soil, and even after being squeezed between the hands as forcibly as possible, it still retained nearly three times its own weight.

The facility with which sandstones absorb water is illustrated by the quantity of water which they contain both in their ordinary state and when saturated. Even granite always contains a certain percentage of water, and in the dry state is rarely without one and a half pint in every cubic foot. Sandstones, however—even those fit for building purposes—may contain half a gallon per cubic foot, and loose sands at least two gallons.

Limestones contain very large quantities of water, not only in cavities underground, but in crevices of the rock, in spaces between strata, and in faults. Dry compact limestones contain half a gallon of water in every cubic foot. Bath stone contains at least a gallon and some magnesian limestones one and a half gallon. Chalk is as absorbent as loose sand, and contains at least two gallons per cubic foot when saturated.

It is not easy to realise the magnitude of these quantities, although the results have been determined very accurately by calculation and experiment. If we limit our estimate to an area of chalk downs 50 miles in length, 10 miles wide, and 300 feet thick, we shall find that the total rainfall on the surface (taken at 30 inches per annum) will amount to 225,750,000 gallons; while the water contents of the rock, if only half saturated, would be more than 660,000,000 gallons, or nearly three years' total rainfall, and fully 12 years' average supply, even if there were no loss by evaporation, and no circulation underground. It must be evident, then, that there is an unlimited power of absorption in such rocks, and as water is distributed through them rapidly and thoroughly, they may be regarded as large receptacles partly filled, but in which the water is constantly in circulation, rising regards water supply, does not in any way affect the question of drainage. For all practical purposes it may be assumed that after evaporation and the wants of vegetation have been supplied, the balance of the rainfall, &c., remains to be carried off by drainage. The rapidity with which this amount of water will percolate through the soil is dependent on the density of the soil and its affinity for water, on the depth of the drains, and on the distance between the drains—or, in other words, the angle of inclination; but ultimately it all makes its exit by the drains. It is this water that drainage has to provide for and carry off. Yet cases do occur where, owing to the presence of springs and water of pressure, more water is sometimes discharged by the drains in a single month than falls in rain upon the surface of the field in a whole year. The only safe rule is to provide pipes of sufficient

and falling according to the influence of past and present weather. The longest succession of the driest seasons can never exhaust them; the heaviest rains repeated for years can never fill them. Other absorbent rocks exhibit the same general features in a different degree, and all assist in the general circulation, the water-level rising after rain and sinking by evaporation during drought, so as never to leave the surface either absolutely wet or perfectly dry.

Schubler, in his experiments, found that the power of soils to contain water was in the following degree:—

Kinds of Earth.	A cubic foot of soil weighs		A cubic foot of the wet earth contains of water
	In the dry state	In the wet state	
	lbs.	lbs.	lbs.
Silicious sand . .	111·3	136·1	27·3
Calcareous sand .	113·6	141·3	31·8
Sandy clay . . .	97·8	129·7	38·8
Loamy clay . .	88·5	124·1	41·4
Pure grey clay .	75·2	115·8	48·3
Humus	34·8	81·7	50·1
Garden mould . .	68·7	102·7	48·4

capacity to carry off the greatest possible rainfall, &c., within the shortest period. The greatest fall of rain is not always in those districts having the greatest number of rainy days. In northern latitudes it has also to be considered how far the melting of snows may influence floods in winter or in spring. Very much, at the same time, depends on the porosity of the soil, and the rapidity with which the rainfall or the melting snows will percolate to the level of the drains.

Conditions influencing the Size of Pipes.—It is seen, then, that in deciding upon the proper size of pipe there are a great many conditions to be taken into account. Amongst these we have—

The length of the drain.
The depth of the drain.
The rate of fall.
The distance between the drains.
The porosity of the soil.
The greatest daily rainfall.
The water of springs, &c.
The loss by evaporation and the requirements of vegetation.

Size of Pipes for Minor Drains.—The capacity of the pipe should, properly, be just sufficient to carry off the maximum flow of water, and no larger. If too large it makes the flow sluggish, and is apt to allow the sediment to lodge in the bottom of the pipes, and so eventually choke the drains. Mr. Parkes was a strong believer in the sufficiency of 1-inch pipes for minor drains. He found that pipes of this size, placed 24 feet apart and 4 feet in depth, were able to carry off a fall of rain equal to 2½ inches in 12 hours—a rainfall which is quite unknown in this climate. But with different soils Mr. Parkes might have experienced different results. At any rate, practice seems to say that 1-inch pipes are not reliable, for they are now never used. The sizes in general use for minor drains, up to say 12 or 15 chains in length, are either 2-inch pipes for the whole, or 1½-inch pipes for the upper ends of the drains and 2-inch pipes for the lower ends. Where the drains are longer, 2½ or 3-inch pipes may require to be used towards the outlet. Small pipes are unquestionably passing out of favour, not only with ourselves but in America. Professor Knapp states that at the late Illinois Tile-makers' Convention only two of the fifty firms represented were manufacturing 2-inch pipes.

Main Drain Pipes.—For main drains the sizes vary from 3 inches up to 18 inches. It is usually reckoned, however, with our average rainfall, that—

	In clay soils.	In free soils.
Pipes of 3 inches diameter will drain	6 acres	4 to 5 acres.
„ 4 „ „	9 „	6 „ 7 „
„ 6 „ „	25 „	20 „ 22 „

The main drains being receivers rather than collectors, their required capacity will always be ample if they are made equal to the united capacity of the minor drains which act as feeders to them. As, however, the latter seldom run full, a smaller-sized main will generally suffice; but if the capacity of the latter has been rightly estimated, the size of the mains ought to be proportioned to them.

Formula for required Size of Main Pipes.—The rule by which to calculate the size of main drain pipes is this:—

The square root of the number of small pipes multiplied by their diameter will give the required diameter of the main pipe.

Suppose, for example, that there are 16 small drains having 2-inch pipes—

$$\text{Then } \sqrt[2]{16} = 4 \times 2 = 8 \text{ inches},$$

is the size of pipe required in this case.

Flow of Water through Pipes.—In any calculations as to the discharge of water through pipes of a given size, it is assumed, of course, that the pipes run full, that they are free from twists, straight, smooth, and accurately laid. Even then, water flowing through them has to overcome the opposing forces of friction, adhesion, and the action of water entering the drain. "Friction will be inversely as the diameter of the pipe, and the other forces directly as the agitation of the flowing current. The velocity of the water in different drains will consequently be as the square roots of the respective sizes of their angles of inclination, minus the effect of these counteracting forces." Velocity depends not merely on the amount of fall or inclination given to the drain, but also on the pressure or head of water behind it.

The formula for the discharge of water through straight, or nearly straight, long lengths of circular smooth pipes is—

$$17{\cdot}03 \sqrt{\frac{d^5 h}{1}}$$

d being diameter in inches, 1 length in yards, and *h* head in feet, the discharge being in gallons per minute.

Assuming that a 12-inch pipe with a fall of 1 foot in 1,100 yards runs full, the discharge will be—

$$17{\cdot}03 \sqrt{\frac{248832 \times 1}{1100}} = 17{\cdot}03 \times 15 = 255{\cdot}45 \text{ gallons per minute},$$

or say 250 gallons per minute, equal to 15,000 gallons per hour.

Area of Pipes of different Diameter.

Diameter in inches.	Area in sq. inches.	Diameter in inches.	Area in sq. inches.
1	·7854	9	60·617
1½	1·7671	10	78·540
2	3·1416	11	95·033
2½	4·9087	12	113·097
3	7·0686	13	132·732
3½	9·6211	14	153·938
4	12·566	15	176·715
5	19·635	16	201·062
6	28·274	17	226·980
7	38·484	18	254·469
8	50·265		

CHAPTER VII.

LAYING PIPES.

Arrangement as to laying Pipes.—The laying of the pipes should be confided to a careful and trustworthy workman, who is paid day's wages, as more attention in the performance of the work is then insured, than when it is done by the drainer as piece work. In any case, it is best to have the drains cut and filled by one party, and the pipes laid by another. The pipe-layer must be very particular that the drains are of the stipulated depth, the bottoms true and smooth, and the fall properly graduated, before he lays a single pipe; and after laying the pipes, it should also be his duty to put in the first covering of earth, say 3 or 4 inches deep—"blinding" it is called—so as to prevent any displacement of the pipes when the digger comes back to hurriedly fill in the drain.

Imperfect Pipes to be rejected.—As many pipes are found to be more or less warped, great attention is demanded in laying them; such pipes being apt to alter their position after the earth is again filled in, if not well and carefully laid. If a joint is too open, and any two pipes will not fit properly, the workman must take out the last laid pipe and try another.

The Pipes to be laid on a Smooth Bottom.—A very small pebble in the bottom of a drain will sometimes prevent a pipe being laid securely. Or it may have happened that the digger found it necessary to remove a small boulder from the bottom, thus leaving a depression some inches deep. All such hollows should be rammed full of hard earth before the pipes are laid, so that one end of the pipe laid over it may not be forced down by the superincumbent pressure, and so destroy the continuity of the channel. The pipes should be laid as close and tight as possible, and the clay carefully packed around them, to keep the fine particles of earth from washing in. There is no danger that the water will not find its way in. As we have seen elsewhere, the inlet area, even in the case of the most closely-laid drain pipes, is many times greater than the outlet area of the pipe at the mouth of the drain.

Packing.—It is frequently recommended to pack sod or turf around and over the pipes to keep out sand and silt; but this practice is far more likely to aggravate the mischief than prevent it. The finest particles of soil are contained in the top spit, and turf or soil is so porous, that, when laid immediately over the pipes, the silt is straightway washed into the drain. In draining quicksands, alluvial deposits, and the like, the only safe plan is to cover the pipes lightly with clay or some solid earth.* In draining the Morecambe Bay intake the pipes were embedded in peat moss, to prevent the fine sand filtering into them. It is also well, in cases of running sands, or other strata of a yielding watery nature, to have the drains bottomed out very quickly, and the pipes immediately laid and covered, so that there may be no displacement of the pipes, by the rising of the bottom or the falling in of the sides.

* In such circumstances the use of collars may be advantageous.

Instruments for laying Pipes.—The common pipe-layer (Fig. 40) is an instrument invented by Mr. Parkes, and is specially adapted for laying round pipes in deep and narrow trenches. The workman, standing on the bank or edge of the drain, hooks up a pipe and deposits it easily and accurately in its right place. On hard and stony soils, however, where the ground is full of small stones and gravel, and where, consequently, the bottom of the drain cannot be cut the exact width of the pipe, and the channel is less true, it is almost impossible to lay pipes satisfactorily by this instrument. In such places, unless laid in collars, or carefully placed in clay, the pipes are very apt to get out of place and thereby effectually stop the drain.

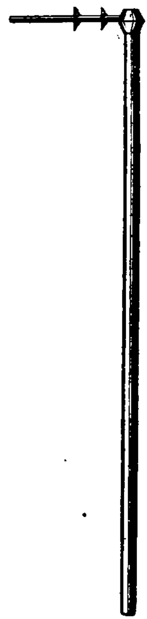


Fig. 40.

In order to obviate this difficulty, and also to prevent the workman displacing the pipes at the moment of packing, Mr. M'Adam, of Bath, contrived an instrument for laying pipes which rendered this displacement impossible. This instrument is sketched in Fig. 41, and consists of a rod of dry ash seven feet in length, and the diameter just small enough for the pipes to thread easily into it, with a socket and handle at one end—the latter of iron, 9 inches in length, and terminating in an eye, set at right angles to the handle, for receiving the rod.

"On the rod so fixed, thread six pipes, when three inches of the rod will remain uncovered; lower the whole into the drain by means of the bent handle, passing the three inches of uncovered rod into the last pipe in the drain. Leave the six pipes and the machine as they are, in the bottom of the drain, and pack them down firmly with the material excavated from the

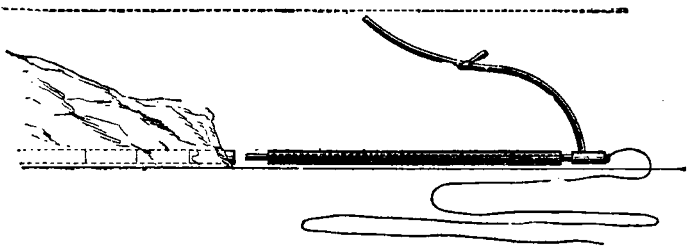


Fig. 41.

drain, even to ramming or treading it in, for it is impossible to displace the pipes by so doing. Then, having packed them tightly, withdraw the machine by means of a long cord, previously hooked to the eye in the socket, standing at some distance up the drain: thread on six more pipes, and proceed as before."

Where to begin laying the Pipes.—In laying pipes with either of the above-mentioned implements, it is best to begin at the lower end of the drain and work up the hill. Where the pipes are laid by hand, however, this plan is just reversed; it is then found better to begin at the top, and lay the pipes down the hill, the workman walking backward in the trench, and taking the pipes from the bank, where he had previously placed them so as to be conveniently within his reach.

Cost.—Pipe-laying, as already said, is best done at day's wages; but it is often done by the piece. Where piece-work is preferred, the price paid in this country varies from one halfpenny to one penny per rod, of 5½ yards, according to the character of the trench bottom. A workman good enough to be entrusted with pipe-laying will expect to earn at least 4*s*. per day, so that at ½*d*. per rod he ought to be able to lay at least 96 rods of drain in a day, and at a 1*d*. per rod not less than 48 rods. The price is the same whether the pipes are laid by hand or by the aid of the pipe-layer.

Junctions.—The junctions between the pipes, of both small and main drains, should be very carefully made. Junction pipes for the purpose, that is, pipes having the first branching pipe of the parallel drain fixed to the pipe of the main drain, should be got from the tile-works. If it is impossible at any time to obtain these junction pipes, the holes into the leading pipes require to be fitted very exactly, and clay firmly rammed all round about. The man laying them should carry a tool for dressing warped pipes, and a sharp chisel and mallet for taking out holes. A miniature pick-axe is often used for these purposes, and is at the same time useful for smoothing any irregularities that occur in the bottoms of the drains.

Junctions should not be made at right angles. This impedes the flow. It has been found, for example, that where the resistance due to a junction at right angles was 316, that due to a curved junction of 5 feet radius was 146, while that for a curved junction of 20 feet radius was only 100; thus showing the increase of resistance with a junction at right angles to be over 200 per cent. over the junction of 20 feet radius.

But this is not all; attention should be paid to the manner in which the curved junctions are laid down. Thus it is too frequently the way to join the curve to the pipe by a hole placed in the middle of the periphery of the latter, instead of level with the bottom. The gain of effective discharge by the adoption of curved junctions over junctions at right angles, is in many cases rendered nil by neglecting to join the curve at the bottom of the pipe. The practice here recommended prevents any deposit lodging in the bottom of the main pipe.

Order of Working.—The rule in making drains is to begin with the complete formation of the main drain, and then proceed with the parallel drains, from the point where they enter the main drain to their upper extremity. In filling up, the order is reversed, and the completion of the drain commences at the upper end, and proceeds to its termination at the entrance with the main drain. It is desirable to have the entire length of the drain opened before any portion of it is filled in, so that a right inclination may be secured; but whether this can be done or not depends on the nature of the soil. If the sides will not stand, the pipes must be laid, and covered in immediately the digging is finished.

Filling-in Drains.—The earth when returned to the trench after the pipes are laid should occupy the same position as it did before it was excavated, that is, the top spit which was first in the digging should be the last to be filled in. It is a mistake to believe that the bottom clay will do harm if put next the pipes. The air which enters the soil through the pipes will soon oxidise the clay and prevent it from either cracking or puddling. The earth as it is filled in should be well packed and rounded up to the land level, so that no open channel remains to draw off water from the surrounding surface. On old grass lands a halfpenny per rod extra is usually allowed for replacing the turf.

CHAPTER VIII.

COST OF DRAINING.

THE cost of draining is principally dependent upon the labour of cutting and filling the drains, the material composing the drain, and outlet for discharge. This last varies with the ground, and can only be included in a general estimate where the surface is undulating. It was formerly held that the cost was equally divided between the labour and material, but with the introduction of drain pipes, and especially since the improvements in making them, there is a considerable balance in favour of material.

The following table shows the number of rods and the number of pipes per acre, with drains at various distances apart:—

Distance between the Drains.	Rods (5½ yds.) per acre.	12-inch pipes.	13 inch pipes.	14-inch pipes.	15-inch pipes.
Feet.					
15	176	2,904	2,680	2,489	2,323
18	146	2,420	2,234	2,074	1,936
21	125	2,074	1,915	1,778	1,659
24	110	1,815	1,676	1,555	1,452
27	97	1,613	1,489	1,383	1,290
30	88	1,452	1,340	1,244	1,161
33	80	1,320	1,219	1,131	1,056
36	72	1,210	1,117	1,037	968
39	67	1,117	1,031	957	893
42	62	1,037	958	888	829

"The differences in the quality of soils, that lead to differences in the depth and distance of the drains, are also such as to affect the cost of digging the drains. An increase of depth necessarily causes an increase of cost, from the circumstance of more earth having to be moved. But the same reason that causes drains to be made closer, namely, the stiffness of the soil, renders them more difficult to dig, and hence increases the price of digging. This will explain how it happens that the cost per rod is often greater, not only as the depth increases, but as the distance of the drains is less. Of two soils drained at the same depth, the expense of draining a rod (provided both are alike free of stones and boulders) will be least in that where the drains are farthest apart, which is where the soil is of the freest or least tenacious description."

The cost of cutting and filling varies from 4*d.* to 1*s.* per rod of 5½ yards, according to the depth of the drain and the hardness of the substrata. In Gloucestershire at the present time 3-feet drains cost from 6*d.* to 8*d.*, and 4-feet drains from 8*d.* to 10*d.* per rod.

From Banffshire, Mr. C. Y. Michie writes: "Drainage work is now from 10 to 15 per cent. cheaper than it was three years ago. The present prices for 3½-feet drains in Banffshire, including cutting, laying tiles, and filling in, is from 13*s.* to 17*s.*, according to soil, per 100 yards." Reducing Mr. Michie's yards to rods, and deducting 1*d.* per rod for pipe-laying and finishing, the cost of cutting and filling, as given by him, is found to be 7½*d.* to 10½*d.* per rod.

In his evidence before the Royal Agricultural Commission Mr. Bailey Denton, speaking as to the cost of drainage, says: "When I began draining in 1849 I was paying 1*d.* per yard run for 4-feet drainage. That is 5½*d.* a rod of 5½ yards. I now pay 7*d.* to 8*d.* a rod for the same thing. . . . . I should say that the increased cost of draining has been 35 per cent."

Suppose the drains are made 3 feet deep, and cutting and filling costs 7*d.* per rod, then the

COST PER ACRE AT DIFFERENT WIDTHS WILL BE:

—	18 feet apart.			21 feet apart.			24 feet apart.			27 feet apart.			30 feet apart.			33 feet apart.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Cutting and filling	4	5	2	3	12	11	3	4	2	2	16	7	2	11	4	2	6	6
Pipes, 14 in. long and 2 in. dia. at 25*s.* per 1,000..	2	11	10¾	2	4	5½	1	18	10½	1	14	6¾	1	11	1	1	8	3½
Allowance for mains and outlets	0	3	6	0	3	9	0	4	0	0	4	3	0	4	6	0	4	9
Pipe-laying, at ¾*d.* per rod	0	9	1½	0	7	10	0	6	10½	0	6	0¾	0	5	6	0	5	0
Cartage	0	4	3	0	4	0	0	3	6	0	3	3	0	3	0	0	2	9
Superintendence .	0	4	9	0	4	6	0	4	3	0	4	0	0	3	9	0	3	6
Total......£	7	18	8¼	6	17	5½	6	1	8	5	9	11½	4	19	2	4	10	9½

The cost per acre, it is seen, ranges on the above scale from £4 10*s.* 9½*d.* at 33 feet apart, to £7 18*s.* 8¼*d.* at 18 feet apart. Deeper drains in hard soils will cost more in cutting; but upon easy digging soils 3-feet drains will be accomplished at considerably less than 7*d.* per rod.

Drainage Companies' Charges.—Under the Public Money Drainage Act of 1846, Land Improvement Companies have undertaken and carried out a great deal of the land drainage that has been done in this country. These companies have undoubtedly afforded great facilities to landlords who wished to borrow money for the improvement of their estates.

The charges made by these companies are moderate.

For loans under £500, repayable, principal and interest, in thirty-one years, the charge is £6 7*s.* 7*d.* per centum per annum; which is calculated at 5 per cent., the difference being the amount paid off the principal. For loans above £1000, the charge is calculated at 4½ per cent., and amounts to £5 16*s.* 8*d.* per centum per annum, when spread over twenty-five years. If we take the present cost of drainage at £7 per acre, the annual charge on this sum would amount to 7*s.* or 8*s.* per acre.

It has no doubt been advantageous to many tenants to pay an extra rent of 7*s.* or 8*s.* per acre, in return for getting the wet lands they occupied drained; but in paying land improvement rates, calculated to redeem both principal and interest in twenty-five or thirty-one years, as the case may be, the tenant, let it be remembered, bears the whole cost of the improvement. It is right and fair that the occupier for the time being should pay simple interest on the outlay, seeing he is to reap any increase in the produce of the land. The redemption-money, on the other hand, ought clearly to be chargeable on the landlord, whose property is permanently increased in value by the improvement.

Of course, if a tenant is taxed on his own improvements, by having his rent permanently raised, after redeeming the outlay, he has good reason to object. To this, and to the after expenses attendant on successful drainage, which if borne at all must be borne by the occupier, Mr. Bailey Denton attributes the fact that the amount of drainage executed in this country has been declining for the last ten years. In his evidence before the Royal Agricultural Commission, he says: "The disinclination of tenants to pay the increased rents necessary to relieve their landlords of loss after borrowing the money, and the consequent indisposition of the landlords themselves to lay out money in drainage, is due in a great measure to the fact that to develop the full benefit of under-drainage, and counteract the effect of successive wet seasons, when several follow each other, involves considerable outlay on the part of tenants, in deeply cultivating the surface, and in laying flat lands which are formed in ridges and furrows. . . . But owing to the additional expense of these after operations, the work is seldom done, and so the full benefit of the drainage is never obtained. The tenant, however, pays up the outlay through compound interest, and the letting value of the land is permanently increased, at the tenant's expense, and to the landlord's advantage."

that due to a declivity of the height between high and low water levels in the whole length of the canal, and its hydraulic mean depth, when full, up to the middle water-level."*

Amount of Fall necessary for Main Drainage Canals.—As tidal lands usually present a perfectly level surface, those engaged in the drainage of them

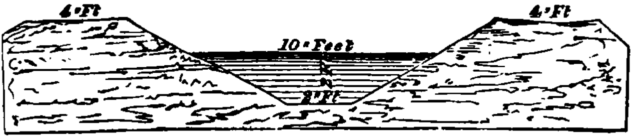


Fig. 42.

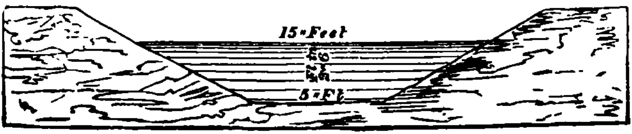


Fig. 43.

Fig. 44.

are often discouraged by the difficulty of obtaining sufficient fall for the drains. It has, however, been proved in practice that a main drainage canal or trench, "30 feet wide and 6 feet deep, giving a transverse sectional area of 180 square feet, will discharge 300 cubic yards of water in a minute, and will flow at the rate of one mile per hour, with a fall of no more than 6 inches per mile."† In every case where that amount of fall can be given to the main canal, it may, therefore,

* Rankine. † Mr. Smith, of Deanston.

be relied on as ample and sufficient. Figs. 42, 43, and 44 represent sections of drains of large size adapted for works of the kind here referred to.

Demerara Field System.—In British Guiana, where all the lands under sugar cultivation have been reclaimed from the tides, and the surface of the fields is 4 to 5 feet below the level of ordinary high-water mark, the drainage question has for many years been a standing difficulty with the planters.

Most of these lands were empoldered by the original settlers, the Dutch, in the eighteenth century. A front dam is thrown up against the sea, a back dam against the savannah and bush waters; and also two side-line dams. The rainfall and drainage waters are discharged through a koker or sluice placed in the front dam; and usually a small koker is put in aback, to take in fresh water for the navigation trenches, and also for field irrigation in dry weather. The empoldering done nowadays is seldom more than taking in a fresh depth aback of the older cultivation, which right is secured to most of the estates in their grants of the lands.

Drainage and Navigation System.—When the dams are made up, and the land cleared, the navigation and drainage systems are next laid out, and the field outline and plan is then complete. First a main drainage trench is opened behind the front dam, and carried round the inner side of each side-line till it reaches the back dam; these trenches being in part at least dug out in forming the dams. Next, a centre main navigation canal is dug from the back dam to the buildings in the front of the estate, with a walk alongside the canal called the middle-walk. Then at every 36 rods along this centre canal, at right angles, right and left, are dug smaller trenches, which are connected with the main one, and the navigation system is complete. Each field is thus 100 × 36 = 3,600 rods, 12 acres. Each field is again divided into 12 beds, by eleven open drains, each 2 feet wide, and opening into the side-line trench, which thus receives the dis-

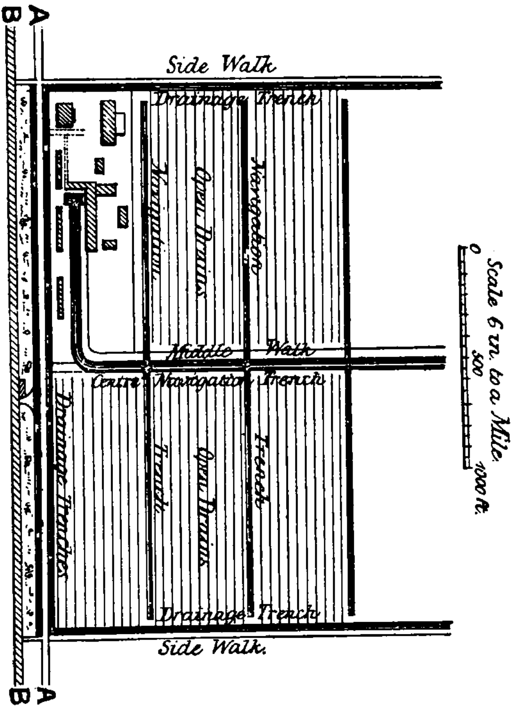


Fig. 45.

charge of all the small drains from the back to the front dam, where the koker lets the accumulated waters out to sea at low tide.

The internal arrangement of the estate thus resembles a system of irrigation on a large scale, in which the middle-walk canal is the feeder, and the cross canals the irrigating channels, the drains drawing off

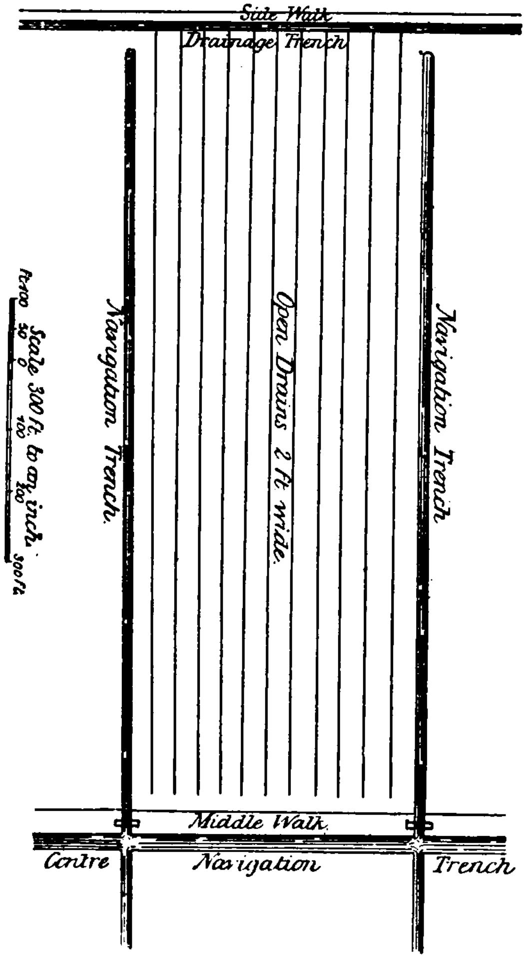


Fig. 46.

the surplus water which is passed on by the side-line trenches to the sluice or koker. Fig. 45 shows the field system in Demerara, and Fig. 46 the drainage and navigation system.

Evils of the Open Drain System.—It will be seen that this open-drain system causes an enormous waste of land. That, however, is the least loss. Land is cheap in Demerara, but labour is dear, and the open drains must be held responsible for the costly system of field cultivation which is necessitated from the obstacle thereby offered to implement tillage; not to mention that the open drains and trenches give increased labour and trouble by propagating the spread of water grass and weeds, which are terrible pests in that tropical climate.

Experiments in Tile Drainage.—The emancipation of the slaves, and the removal of the protective duties which had long favoured colonial sugars, doomed the old Demerara system of cultivation. From these days forward the planter has been struggling with a difficulty which can be surmounted only in one way. When the crisis of 1846 made the need of a rational system of agriculture so severely felt in the colony, the important experiment of subsoil drainage was attempted. A field on Plantation La Pénitence was granted for the purpose, the Combined Court having previously voted the sum of 2,000 dollars towards defraying the expenses of the experiment, which was carried on under the immediate superintendence of Dr. Shier.

"The field," says Mr. McRae, one of the Committee appointed to watch and report, "was tile-drained with three-inch tube tiles, laid in drains 15 feet apart, running from the inner end of the field to a reservoir at the outer end, adjoining the main draining trench of the estate, but separated from it by a dam.

"The distance from the one end of the field to the other was about 45 roods, Rhynland measure, and the fall given to the tiles about 10 inches in that distance; they having been placed 20 inches under the surface of the land at the upper end of the field, and 30 inches at the lower end, or reservoir. There was a four-horse high-pressure steam-engine employed to pump the water received in the reservoir from the tiles into the side-line trench of the estate, which was run off every tide. Every possible justice was done in digging the drains and in laying tiles with mathematical precision, they were covered over with divots, and the drains packed with clay; the whole field being stiff clay soil.

"There was an adjoining field of about the same area cultivated with open drains in the ordinary manner. The result of this experiment for the first crop was, that the thorough-drained field gave about 75 per cent. more sugar than the open-drained field, and made very nice sugar, which sold 1*s.* 6*d.* per cwt. over the price obtained for the sugar from the open-drain field."

The effect of this flattering prospect was electrical and instantaneous. For the time being everybody believed in and was ready to extol the advantages of tile drainage. It was the one thing needful to the prosperity of the planter. Resolutions in its favour were immediately adopted by the Honourable the Court of Policy of the Colony of British Guiana, and petitions to the same effect were signed by all the members of the Combined Court, by the whole body of proprietors and planters, and by hundreds of other residents in the colony, praying the British House of Commons to grant a loan of money to be expended in draining the sugar plantations.

An Extract Minute of the Court of Policy, of March 1, 1847, which I find in one of the blue-books of that period, and a petition annexed to it, contain a series of resolutions on the subject, amongst which are the following:—

"*That* one of the greatest difficulties with which the planters have to contend is, that the system of drainage in universal use in the colony is only adapted to a state of society such as existed prior to the emancipation, when manual labour for every field operation was abundant, effective, and cheap.

"*That* this system of drainage, known as the open-drain and round-bed system, is altogether incompatible with the employment of cattle labour, the use of the most approved implements, and with the introduction of the numerous improved methods of agriculture so well known elsewhere, and which, but for this obstruction, would be at once gladly adopted.

"*That* it can be shown that, were the planters enabled to adopt a more perfect system of drainage, admitting of the 'thorough-drainage,' and laying flat of the surface of the cane-fields, many of the difficulties under which they at present labour would be obviated.

"*That* it is the opinion of this Court that the following, among other advantages, would accrue:—

"(1.) The general use of cattle labour and implements, whereby the present difficulties in respect of high-priced, ineffective, and incontinuous labour would be greatly reduced.

"To illustrate this point more fully, your petitioners may state that in the best farmed districts of Scotland, on a liberal computation, which embraces both green-crop weeding and harvest work, six adults, with four good Clydesdale horses, two ploughs, and the other implements corresponding to the two ploughs, are known to labour 100 acres on the four-course rotation. In this colony, to cultivate 100 acres and manufacture the produce, fifty negroes, working well and continuously, are required. But as the Scotch labourers only partially manufacture the produce, and our labourers both cultivate the sugar-cane and manufacture the sugar, it is but fair to double the number of Scotch labourers per 100 acres, to secure a fair comparison. Hence it follows, that the four horses, two ploughs and corresponding implements, effect a saving of thirty-eight labourers per 100 acres of cane cultivation and manufacture, a saving which it is obvious that no measure of immigration can possibly supply to the colony at the same cheap rate, even if it were otherwise equally valuable.

"(2.) That the introduction of all the well-known improvements in agriculture applicable to the colony, as appears both from a consideration of principles and from the experience of other colonies, would be rendered in this colony practicable and easy.

"(3.) That the quantity of the produce would be increased, and its quality improved.

"(4.) That cane cultivation would be less liable to the effects of protracted wet and drought, which at present occasionally interfere with the large returns which might otherwise with considerable confidence be relied on.

"(5.) That the effect on the labouring classes themselves, of substituting improved implements for the present very imperfect methods, would be highly beneficial, and would tend to improve and elevate the condition of such especially as already possess small lots of land, the want of efficient drainage being a main cause of the very limited and imperfect cultivation of almost all such lots.

"(6.) That improved drainage and cultivation of the soil would be found to prevent disease, to moderate the virulence of epidemics, and to improve the general health of the community."

In forwarding the Resolutions and Petitions to Earl Grey, who was then at the Colonial Office, Governor Light warmly supported them in his accompanying despatch, and earnestly recommended the subject to his lordship's favourable attention.

Earl Grey's refusal to support the petitions to Parliament caused the colonial ardour for tile-drainage to subside as rapidly as it had arisen. Without debating the policy of such a loan, there is no reason to doubt that, had it been granted, the planters would have earnestly set about the work of tile-drainage, and speedily have solved for themselves all the difficulties in the way of its successful application. But it was fated to be otherwise. The loan for drainage was not forthcoming from the mother country, and the colonists turned their whole energies in the direction of immigration, on which, though only affording a temporary solution of the difficulty, they were not slow to provide and to expend much more than the amount of the loan they had asked for to enable them to tile-drain their lands. The La Pénitence experiment was neglected, or imperfectly carried out, and it seems to have been abandoned altogether at the end of the second year, after some 5,000 dols. had been uselessly expended upon it. But having quoted Mr. McRae's account of the early part of the experiment, let me give the conclusion of it in his own words.

"During the second year," he says, "the drains began to exhibit symptoms of silting; and notwithstanding the reservoir being kept pretty clear of water by the pumping-engine, the field got frequently inundated during heavy rain. At the expiry of two years, I examined the tiles at various distances from the reservoir, and found them to be nearly silted up at the upper end of the field; the silting in them gradually diminishing as I approached the reservoir, until within two rods of the reservoir, where the silting disappeared entirely. In consequence of this silting, and the inundations caused thereby, the canes on the upper half of the field were puny and miserable, gradually improving, however, towards the reservoir. The result of this year's crop showed a falling off of nearly 100 per cent. as compared with the yield of the previous year, and the sugar also fell off much in quality. I watched this experiment from first to last, with great attention and much interest, *because I saw clearly that by a successful system of thorough drainage the prosperity of the Colony would be materially secured*; inasmuch as two-thirds of the manual labour now employed in cultivating the land would thereby be saved, and brute labour substituted in its stead. The land under thorough drainage would then be a perfect level, and every facility afforded for the use of the plough, and all other agricultural implements worked by quadrupeds; whereas, at present, under a system of open-drainage, it has been found profitably impracticable, and manual labour is the sole power employed to cultivate the soil."

When the next attempt was made at tile-drainage in Demerara is immaterial. Little or nothing seems to have been done at it during the 20 years succeeding 1846. Since 1866, however, it has gradually progressed, until at length it begins to assume no inconsiderable proportions. But even now, there are not perhaps more than 2,000 acres tile-drained, out of some 150,000 acres under cultivation in the colony.

Objections against Tile Drainage answered.—There is no doubt that pipe drains, under the Demerara conditions of soil and rainfall, are very liable to get choked up with silt. But it is obvious that silt can only enter the pipes by one of two ways—either downwards through the superincumbent soil, or from the mouth of the drain. If the silt enters the pipes from above, the presumption is that the drains are too shallow, or that the pipes have been improperly laid; and the remedy will be either to deepen the drains, or to secure the pipes by laying them in collars, or by packing them around with clay. If the silt enters the pipes by the mouths of the drains, there are also two ways of effectually guarding against it: *first*, by trapping the mouths of the drains; *second*, by always keeping the water in the drainage canals at a lower level than the drain outlets.*

The remarks of Mr. McRae show that in the La Pénitence experiment the silt entered the pipes by the mouths of the drains, and not from the soil above. If the latter had been the case, the silt would have accumulated towards the mouth of the drain; but Mr. McRae says that the silt was greatest at the upper end of the drain, and that it gradually diminished towards the lower end, which is proof positive that it must have entered by the mouth of the drain. This being so, it could have been prevented by trapping the drains, or by constantly keeping the water in the drainage canals below the level of the drain pipes—by natural means if possible, but by the aid of machinery if needful.

* As an additional precaution, it may be wise to have one or more deposit cisterns built in the drain, to catch any silt that may enter the pipes.

Another objection urged against tile drainage in Demerara is, the excessive humidity of the climate, and the declared impossibility of underground drains to carry off the immense rainfall with sufficient rapidity. It is thought, by those who argue thus, that there is nothing to equal the capacity of open drains and ditches for storing water. This of course is entirely to mistake the purpose of a drain. Yet, if it comes to be a question of storing the water, the body of the soil, aerated to a depth of 3 or 4 feet, has a far greater capacity than any number of open drains. All that is required is to keep the cask running, so as to renovate day by day the water contained in the soil; and this will be found advantageous to the planter in more ways than one. It has been calculated that no less than one-fourth the entire bulk of a moderately well pulverised and moist soil is made up of contained air, so that every foot in depth of this soil is capable of facilitating the escape of water from the surface to the extent of 18,817,920 cubic inches of rainfall per acre. Therefore, apart altogether from the benefits resulting from the renovation of water in a soil, which subsoil drainage alone effects, the open-drain system is not the best one for dealing with a heavy rainfall.

The want of a good outfall is also alleged to be an insuperable obstacle to subsoil drainage in Demerara. This, however, does not weigh more against covered drains than against open drains. Whatever natural drainage there is, it will serve as well for the one system as for the other; and the necessity for aiding the discharge by means of machinery is not at all increased by the adoption of underground drainage.

Natural Drainage.—On the coast of British Guiana the land level, as already mentioned, is about 4½ feet below the level of high water. The following section, Fig. 47, shows the relative levels of the land and of the sea at low water. Spring tides rise from 8 to 9 feet, and neap tides 4 to 6 feet. The average rainfall of the colony, from observations during ten years, is 102 inches; the maximum annual rainfall in that period being 133 inches and the minimum 68 inches. A fall of 6 inches of rain in 24 hours is not unknown in Demerara, and this is in fact the amount of drainage

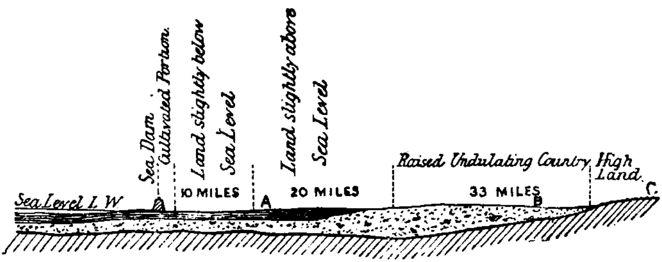


Fig. 47.

water which has to be provided for where the discharge is entirely dependent on natural means. The proportion of the rainfall which is absorbed and evaporated is scarcely appreciable,* even in that tropical climate, during a succession of rainy days, although it amounts to a great deal annually, so that the maximum rainfall during any one day is practically the amount of drainage water which has to be discharged from the embanked area. The quantity of water, therefore, which in this case has to be stored up till the drainage can be opened in the period of any one tide, can seldom or never exceed a rainfall of 1½ inch, which on an estate of 500 acres will be equal to 2,733,750 cubic

* The greatest evaporation in 24 hours, during three years' observation, was ·210 inch.

feet. This is an excessive estimate, perhaps, even for Demerara. In the United Kingdom the greatest rainfall to be provided for in a similar period of time would not exceed half an inch per acre.

Where less than this amount of water can be retained within the enclosure, in the drainage canals and in the pores of the soil, during high water without submerging the drains, some mechanical means will have to be employed, if the land is to be perfectly drained. It is

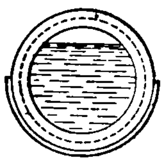


Fig. 48.

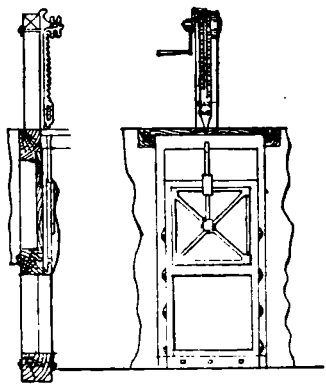


Fig. 49.

well, however, in all cases, to take advantage of natural drainage as far as possible.

The Sluice or Koker.—The drainage outlet is either a sluice, or a cylindrical iron tube or koker. The latter is fitted with a self-adjusting valve door on the outer end, and is usually made 6 feet in diameter, thus affording a sectional area of 28·274 square feet (Fig. 48). The sluice is a vertical doorway, or sliding valve, of timber or iron, moving in guides, and set in a rectangular passage of timber or masonry, the valve being worked by a winch and racket, or by gallows-posts and windlass (Fig. 49). It is usually made to open 13 feet at the base, so that with 6 feet of water on the cill, the sectional area is 78 square feet. With the same periphery the circular koker, if it runs full, will carry more water than the rectangular sluice; but with a small run of water the sluice, with its flat base, has a decided advantage.

Number of Sluices.—One or more large sluices, of the above size, will generally be preferable to a greater number of smaller ones. The expense of these large sluices, and also their danger from the sea, is against them; but the consideration of their stream being powerful enough to keep open the channel to sea is in their favour. In Demerara a single koker usually serves to drain a whole estate, which may be from 500 to 2,500 acres in extent. But the number of acres to be drained by one koker or sluice must be a matter of local experience, as it depends on many conditions besides the sectional area of the water-way.

Level of Sluice Cill.—The level at which a sluice or koker is put in is a point of great practical importance. Where the land is at a very low level, and there is sufficient current to keep the cill of the sluice free from silt, the cill may be laid at the level of low-water mark. If there is no current, however, the cill of the sluice should be placed as far above this level as is consistent with a proper depth of the trenches. It is doubtful if, under any circumstances, anything is gained by having the cill of the sluice below low-water mark. This, however, is often done, with a view to deepening the trenches within the embankment; but as by so doing the head or pressure of water is not increased, there is no advantage. On the contrary; by lowering both the trcnches and the cill of the sluice, the length of run between tide and tide is shortened, and the water, in times of heavy rains, will then actually stand higher in the drains than if the cill of the sluice had been at low-water mark. The maximum run of from 6 to 7 hours is only obtainable by having the bottom of the front draining trench somewhat above the level of low water. The cill of the sluice should be as nearly as possible on the same level. Tidal lands, unfortunately, are seldom elevated enough to admit of this, but in proportion as the cill of the sluice is lowered to low-water level, or below it, the run is shortened, and at neaps, or when the tide is kept up by winds, the drainage is liable to be greatly interrupted.

Forcing an Outlet.—On nearly all tidal lands the natural drainage is frequently impeded by the tides bringing in drift mud, which fills up the sluice channel, and it is a matter of the first moment to keep this channel open. The straighter and the deeper the outfall channel is, the greater and quicker will be the discharge of water. A mode of forcing drainage has been introduced on some of the Demerara Estates, by Messrs. Fowler & Co. of Leeds, and is simply as follows:—A wire rope is laid down the full length of the water course to be cleared and is anchored at the far end. One or more punts, each fitted with an engine and clip pulley, run along the rope, in a similar way to the chain haulage on canals. Behind the punts is attached a set of harrows, which stir up the mud, which in the current of the receding tide is carried out to sea. In this way a channel is made and is afterwards kept clear.

The above-mentioned plan of forcing drainage is not so effectual as having artificial scours by means of reservoirs, relieving basins, or canals and sluices. A canal extending perhaps miles in length, and containing vast quantities of fresh or sea water, if kept full and let off at low water, is able to continue running in plenty for a considerable time with great velocity, and has a very powerful effect in clearing the channel.

The early settlers in Demerara adopted this plan. In laying out their plantations, a space was left between every second estate for a Company canal, which was made available both for forcing drainage and for facilitating navigation. When the water from the creeks or lakes behind the estates gave out in dry weather, advantage was taken of the tidal water to fill the canals. These Company canals, as they are called, are of the greatest value in helping to maintain an efficient system of natural drainage; and recent efforts to improve the drainage of estates have been wisely turned in this direction.

Mechanical Drainage.—If, after taking every precaution to ensure good natural drainage, this fails to keep the level of the water in the trenches sufficiently low to admit of a free and continuous run from the field drains, the natural drainage must be supplemented by mechanical agencies.

On many of the Demerara estates the drainage is now entirely effected by steam power, but this is not to be recommended. Mr. Russell, a leading planter in the colony, puts the first cost for draining plant and engine, equal to the drainage of 600 acres, at not less than £5,000, and the annual charge attending the same at £2 per acre, viz. 24*s*. per acre for fuel and labour and working, and 16*s*. per acre for interest on capital and wear and tear of machinery.

This shows the necessity for taking advantage of natural drainage as far as possible, and of putting the draining-engine to other uses when it is not required for pumping.

The most economical plan of conducting drainage in this manner, "is to provide reservoir room for the greatest floods, and pump constantly at an uniform rate. To provide for the repair of engines, and for accidental stoppages, engines are required in reserve, of power equal to from one half to the whole power of those that are kept at work." *

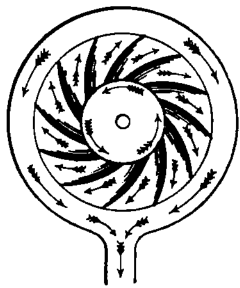


Fig. 50.

The centrifugal pump (Fig. 50) is specially adapted to the lifting of large bodies of water to moderate heights. Its essential parts are—(1) the wheel to which the water is admitted at the axis, and from which it is expelled at the circumference, by the centrifugal force due to the rotary motion imparted to it in passing through the rapidly revolving wheel; and (2) the casing or box in which the wheel works, and by which the entering water is separated from that discharged.

One of Appold's centrifugal pumps, 4 feet 6 inches in diameter, employed in draining Whittlesea Mere, and in keeping up the drainage of 3,000 acres of Fen land, discharged 16,521 gallons of water (equal to 74½ tons) per minute, with a lift of 5 feet. The pump in this case was worked by a 25-horse power engine, and used on an average 60 hours a week; the cost, including coal, oil, repairs, and engineman's wages, was less than *2d.* per hour for every horse-power employed. The cost of draining the 3,000 acres was thus £675, being 4*s.* 6*d.* per acre per annum.

* Rankine.

The great rotary pump, which discharged the enormous cascade of water at the "Centennial" Exhibition at Philadelphia, was able to throw 100,000 gallons per minute. The principle upon which this powerful pump works is that of an ordinary propeller shaft. It is rotated by means of a pulley and a belt from an engine. The shaft is enclosed in an iron casing or tube, and the water is forced up the outflow pipe. Fig. 51 shows a section of this pump.

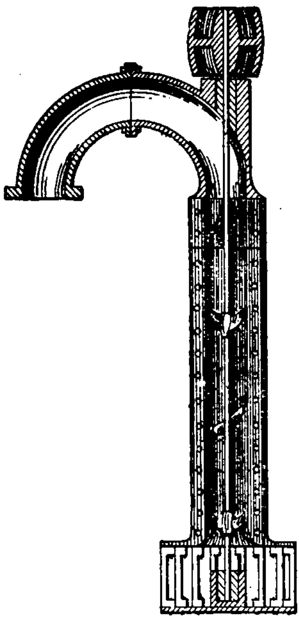


Fig. 51.

"Both in this country and in Holland, windmills were formerly much used for working drainage pumps. This is of course a cheap motor, but experience has shown that the power is too variable to be relied upon for keeping the water to a certain level, which is essential for successful agricultural operations; hence many of the older windmills have been abandoned and replaced by steam-engines, or, if the windmills are retained, they are only used occasionally. The cost of maintenance of old mills, however, is so heavy, that it is often found more economical to take them down and work the pumps by steam. Even in countries such as Egypt, where coal costs from £2 to £3 per ton, or even more, and where there is a steady breeze for several hours almost every day, the windmill is too uncertain a motor to be universally employed. Many other instances might be adduced, but the two extremes, Holland, where coal is relatively cheap, and Egypt, where it is dear, will probably suffice to show that there are comparatively few conditions under which wind power can be economically employed for drainage."

For low lifts, scoop-wheels, worked either by steam power or by windmills, may sometimes be usefully employed instead of pumps. The slow speed of

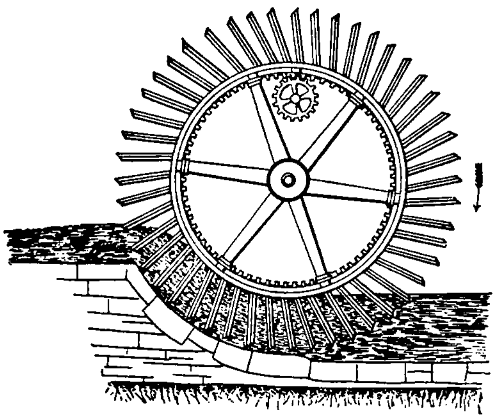


Fig. 52.

working and the ample wearing surfaces are in favour of a low cost of maintenance; but the first outlay will be less for a centrifugul pump than for a scoop-wheel of equal capacity. The flash-wheel is much used in the Fen districts for raising water rapidly short distances. "It is like an undershot-wheel with its motion reversed; in Fig. 52 the arrows show the direction of the current when driven upwards. It must of course be made to fit the channel closely, without touching and causing friction. In its best form, its paddles incline backward, so as to be nearly upright at the time the water is discharged from them into the upper channel. It has been much used in Holland, where it is driven by windmills, for draining the surface water off from embanked meadows. In England it has been driven by steam-engines; and in one instance, an 80-horse-power engine, with 10 bushels of coal, raised 9,840 tons of water 6 feet and 7 inches high in an hour. This is equal to more than 29,000 lbs. raised one foot high per minute by each horse-power, showing that very little force is lost by friction in the use of the flash-wheel." *

A different example of draining by power is exhibited on the Middle Level Drainage Canal, where the waters are discharged over the top of the embankment through 16 parallel syphons, each 3½ feet bore, and 1⅛ inch thick. The summits of the syphons are 20 feet above, and their lower ends 1½ foot below, low water of spring tides. They have flap-valves opening down stream at both ends, and the lower valve can be made fast with a bridle when required. The air is exhausted from their summits, when required, by an air-pump having three cylinders of 15-inch diameter and 18-inch stroke, driven by a high-pressure steam-engine of 10-horse power. The flow of the canal at the inlets and outlets is protected by a wooden apron.

TIDES.

Lunar hours after high water.	Time commonly called
0	High water.
1½	Quarter ebb.
3	Half ebb.
4½	Three-quarters ebb.
6	Low water.
7½	Quarter flood.
9	Half flood.
10½	Three-quarters flood.
12	High water.

* Thomas's "Farm Implements."

TABLE FOR FINDING THE HEIGHT OF THE TIDE AT ANY INTERMEDIATE HOURS OR HALF-HOURS BEFORE OR AFTER HIGH TIDE.

Range	h. m. 6 0	h. m. 5 30	h. m. 5 0	h. m. 4 30	h. m. 4 0	h. m. 3 30	h. m. 3 0	h. m. 2 30	h. m. 2 0	h. m. 1 30	h. m. 1 0	h. m. 0 30
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft in.	ft. in.	ft. in.	ft. in.
High-water	8 0	7 10	7 4	6 9	6 0	5 0	4 0	3 0	2 0	1 3	0 8	0 2
	9 0	8 9	8 3	7 7	6 8	5 8	4 6	3 5	2 4	1 5	0 9	0 3
	10 0	9 9	9 2	8 5	7 5	6 3	5 0	3 9	2 7	1 7	0 10	0 3

The first column gives the several ranges of high water; the low water is supposed to be zero at 6 hours after high water.

CHAPTER X.

EMBANKING.

The work of embanking may be considered under three heads. 1. Embanking lands against the sea. 2. Embanking against land water, or floods. 3. Protection of river banks.

1. *Embanking Lands against the Sea.*—This is a necessary preliminary to the cultivation of all the low-lying lands which are within the wash of the tides, both on the sea-coast and on the banks of tidal rivers. As upon very low flat land, with but a slight fall to seaward, much of the success of an intake depends upon its capability for drainage, the rainfall of the district is an important consideration in such undertakings. A dry climate renders less necessary the means of drainage, whilst a wet climate adds greatly to the difficulty of the situation; still, this objection only involves the question of a greater number of sluices, which are no great expense, and may be aided by steam.

The Line of Direction for a Sea-dam.—This should be considered with reference not only to the extent of the ground to be embanked, but also to its exposure with respect to the prevailing winds. Care should be taken that no abrupt angles or bends be formed, but that their line of direction should be carried in easy curves.*

A still more important consideration in the line of a sea-bank or dam, is its situation with reference to low water, since on that depends the drainage of the lands embanked. The bank should invariably be placed, if practicable, at such a distance back as to leave a solid foreshore. The foreshore is "that portion of the ooze, slob, saltings, or mud-banks which is left unembanked, or on the sea side of the embankment. And there is no feature appertaining to a sea-bank of greater importance than this, since it acts as the advanced-guard to the bank itself, receives the first shocks of the sea, and deadens its force upon the bank, by decreasing the depth and bulk of the wave. The greater, therefore, the width of the foreshore, and the higher above low-water mark, the greater its protection to the bank. In Essex, a county so famous for its sea-banks, the foreshore generally stands several feet above low-water mark, and some hundreds of yards outside the bank; and where it wears away, its edges are scarped and stoned to prevent the loss of so valuable a defence to the sea-dam."† For fuller details on all the points involved in the construction of embankments, the student is referred to Mr. Wiggins's treatise, of which this chapter is in part a summary.

Weight of Dam.—The weight of the dam must be sufficient to counterbalance the weight of the sea against it, that weight being augmented by winds. This condition of weight is so important, that in some cases of light material, such as peat or some kinds of sand, the

* D. Stevenson, C.E., "On the Reclamation and Protection of Agricultural Land."

† "On Embanking Lands for the Sea." By John Wiggins. Published by Messrs. Crosby Lockwood & Co.

safety of the bank entirely depends on it; and, in general, a bank must be *rendered* weighty in proportion to the lightness, looseness, or want of adhesion of the materials of which it is composed, either by its bulk, or by means of more weighty materials, such as stone, laid upon the lighter materials.

The force of the sea water pressing against a bank will be in the compound ratio of its depth and its velocity. Every attempt to reduce these to calculation will be in some degree nugatory, because either may at times exceed the other; but they often act in combination. The bank therefore must be superior to their greatest united strength.

The weight of sea water is 64¼ lbs. per cubic foot. The weight of earth—that is, gravel, sand, and clay mixed—is from 2,500 to 3,500 lbs., or from 1·1 to 1·6 ton per cubic yard. If the weight is 1·5 ton per cubic yard, it will be 373⅓ lbs. per cubic foot. We may, therefore, take the weight of the materials usually employed in building a sea-dam, to be five or six times the actual weight of the quiescent water they have to sustain.

The weight of quiescent water is, however, but a portion of the pressure exerted on the dam; the pressure of wind upon the surface of the sea, and the velocity thus acquired by the waves, produce such a momentum that a vast increase of strength is requisite in a sea-bank to enable it to sustain the weight it will inevitably have to encounter, especially as the bank must not only be equal, but have a power of resistance superior to the most extraordinary augmentations of weight and force of water that can in any likelihood be produced by wind, tides, or currents.

A hurricane has a velocity of 80 miles an hour, and its force is 31·490, say 31½ lbs. per foot; but hurricanes of nearly double this pressure have been recorded. Taking these as average and extreme pressures, let us suppose this increased weight applicable, not only to the surface to which in strictness it would be nearly limited, but to every cubic foot of the whole depth of the dam; in which case it is evident that the pressure of the water will be increased by the wind up to 95¾ lbs., or even 127 lbs., per foot. This will be resisted by the dam, which is of much greater superficial extent, and of much greater weight per cubic foot, than the water pressing upon it, and therefore perfectly able to bear its force increased by the action of the wind.

Materials.—The dam may be constructed of almost any firm materials which will compact solidly together, the best, perhaps, being a mixture of clay and sand. All combinations of walls of masonry with embanking should invariably be avoided, as it is impossible to effect any proper bond or union between the earthwork and the masonry, and such composite structures are likely to result in a failure. (*Stevenson.*)

In cases where the material is not very trustworthy, a dyke, or wall of common puddling, should be carried up in the centre of the dam, of such width, and commencing at such depth below the shore level, as the case may seem to require.

Form of Dam.—The general form of a sea-dam should be such as to receive the waves easily, *i.e.* without any great concussion, or with the least degree of concussion; such as may enable the top of the wave at its highest range to run along the top of the bank without meeting with any great resistance or sudden check.

Width of Dam.—The width of the seat or base of the dam should be regulated by the amount of adhesiveness in the material upon which it is placed, and of which it is built; because it is necessary to guard against any escape of those materials from the drawing out or suction of the sand, by the reflux of the wave, or by the soakage of water under the bank.

The width of the *top* of the bank must, in like manner, within certain limits, depend greatly on the nature of the material used in building it. This is of less consequence in those Fen districts where the top of the embankment has to serve as a roadway, and must, necessarily, be of a great width in any case. In other cases, however, where no such roadway is required and where the materials employed in constructing the bank compact well together, a top width of three feet will be amply sufficient.

Height of Dam.—In regulating the height of an embankment, it is necessary to ascertain the highest point of flood tide, making the summit of the dam about two feet higher than flood level. Embankments settle from $\frac{1}{12}$th to $\frac{1}{5}$th, and this shrinkage must be allowed for in reckoning the final height of the dam.

Slope.—The slope of the bank to the seaward is one of its principal features of strength and safety. Wiggins considered that a slope of 5 to 1 is the best that could be given to any sea-bank; that more was generally unnecessary, but that less was insufficient in exposed situations. In practice, however, it is seldom that the slope given is greater than 3 to 1 towards the water, and 2 to 1 towards the land. The slopes given to the two sides should be such as, if produced, would form an angle at the top of at least 90 degrees; otherwise the upper portion of such bank is liable to be broken away by the pressure of water, which is always at right angles to the face of the slope.*

Delph.—The delph or drain which is dug on the land side of the sea bank or dam for the double purpose of a drain and a fence, should not be too near the foot of the bank, otherwise it may favour percolation of water under the bank, or it may cause the base of the bank to slip and give way. The usual dimensions of the delph when cut, independently of its materials, are 12 feet wide at top, 6 feet wide at bottom, and 4 or 5 feet deep. For a fence against cattle, 3 to 4 feet depth of water is requisite.

Sections of Sea-dams.—Fig. 53, a sectional diagram of a sea-bank, which is here reproduced from Mr. Wiggins's work "On Embanking Lands from the Sea," is, in its general form, supposed to fulfil all the foregoing conditions. It is, however, much too elaborate an affair for an ordinary embankment.

A plain embankment, such as is shown in Fig. 54, 7 feet high, and with a slope of 3 to

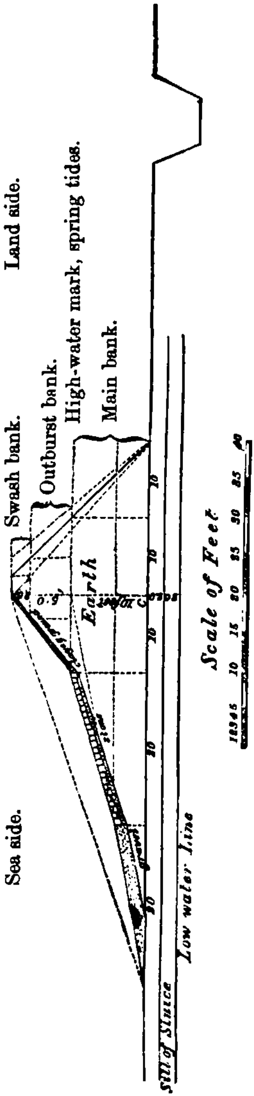


Fig. 53.

* Mr. Baldwin Latham.

1 seaward, was constructed on a coast estate in Demerara last year (1882), at a total cost of 15·62 dollars per lineal rod, and is found to answer its purpose very effectively. This dam was built without the aid of either wheel-

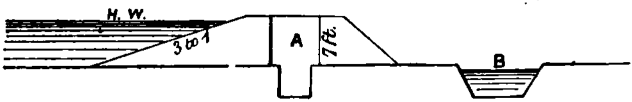


Fig. 54.

barrows, cart and horses, or tramway waggons; the earth used in banking being carried in baskets on the heads of coolies. In this country, where labour is applied differently, the cost would have been considerably less for a bank of the same dimensions.

Labour and Construction.—The labour attending the construction of a sea-bank is performed in this country by gangs, generally consisting of six runners to two fillers, a lad to clear barrows and planks, and three men to pack on the bank; these proportions, however, somewhat differing with the hardness of the soil, the length of run, and other circumstances.

The rate at which the work may be expected to advance, if no special difficulties occur, may be estimated for each filler or shoveller at about

20	cubic yards of	loose sand or mould	per day.
18	„	compact earth	
16	„	ordinary clay	
14	„	hard clay	
12	„	mud	

Tipping must be done over the end of the bank, and not over the sides. If an embankment has been made too narrow, it will not do to tip over the side, as in Fig. 55, to make it up, as the earth will tend to slip away from the end-tipped mass. It is, however, allowable to form two narrow embankments and fill up the gap between them, as in Fig. 56.

2. *Embanking against Land Water, or Floods.*—Not only do tidal lands require to be embanked against the

Fig. 55.

Fig. 56.

sea, but, in most cases, they require to be as carefully protected from waters which come down from the higher grounds lying aback of them, and from the risk of inundation by the overflow of rivers, &c., during floods. In countries where the rainfall is heavy, these flat lands, if they are to be safely cultivated, may require this protection, although there are neither rivers nor high grounds in the immediate neighbourhood aback of them. This is the case in Demerara, where, during wet weather, the rainfall accumulates on the level Savannah behind the estates, and, seeking its natural outlet to the sea, would completely swamp the cultivation if not shut out by an embankment. The embankment in this case is termed the back-dam, to distinguish it from the front, or sea-dam. And as the Savannah waters often gather to a great depth behind the embankment, the requisite height of the back-dam may be as great as that of the front-dam, but less weight of bank will generally suffice for the back-dam. A (Fig. 57) represents a cross section of an embankment for this purpose, the materials for which are obtained by digging a pair of trenches, B, C, alongside of it. B, which is within the intake, serves either as a navigation trench, or for collecting surface water and discharging it into the nearest drainage channel. C is on the outer, or Savannah side of the embankment, and

Fig. 57.

by retaining water after floods, serves as a fence and a protection to the dam from the trampling of cattle and other animals.

3. *Protection of River Banks.*—The tendency of a running stream to rapidly undermine and wash away a sandy, or earthy bank, when the latter is opposed to the direction of the current, is a matter of daily observation in most districts. This action is greater in some rivers than in others, and is not altogether regulated by the geological formation of the bank; but is influenced by the velocity of the stream, the velocity again being influenced by the fall or slope of its surface, and also by its hydraulic mean depth.

An "Agricultural Engineer," writing to the *Albany County Gentleman*, makes some very practical remarks on this subject, which we cannot do better than repeat in his own words. "The course of a stream," he points out, "is subject to the same law which controls the reflection of a moving body, which may strike an obstacle at any certain angle." This law is that "the angle of reflection is equal to the angle of incidence." In the case of a glancing ball on a smooth pavement, the course of the ball is changed by the effect of gravitation after it is reflected, and gradually assumes a curve until it reaches the ground again. So the course of a stream is influenced by the momentum and force of its current, which is, in fact, the force of gravitation. To this variation is due the sweeping curves we see in the bends of streams, and which continually enlarge by the erosive action of the current until the land is washed away very considerably, and much damage done.

"At Fig. 58 is given a diagram of a very common form of the bed and banks of a stream passing through alluvial soil, whether of sand, gravel, or clay. The stream passing the first bend, strikes the bank A, and instead of being deflected at the same angle at which it strikes the bank, it turns with a sweep down stream in the direction of C, but is forced by the resistance of the bank into the gradual curve shown. Passing this curve it strikes again at B, and the erratic course is

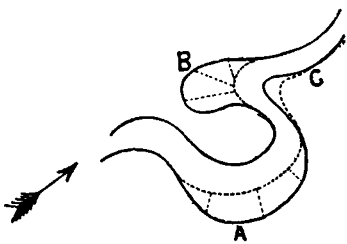


Fig. 58.

repeated. Now in these sweeps the water is forced with considerable violence against the banks, and quickly wears them away, carrying the soil in its whirls and eddies to the opposite side of the stream, where it is deposited, and is formed into an obstacle which still further aids in the work of cutting, until, in the bend shown, it would be carried down the stream to the point C.

"There are two ways of managing a stream of this kind, one by protecting the banks from the erosive effects of the current and preserving them in *statu quo*, or forcing the stream to repair its own damages; and the other is to reform the banks altogether, and by cutting off the bend to recover a good deal of land from the stream.

"The former is best done by means of stakes and brush planted in the stream, as shown by the dotted lines in Fig. 58. It depends somewhat on the size of the stream how this work is to be done; for small streams it may be sufficient to plant rows of stakes in the bed, as shown by the dots, and interweave brush between them. The stakes may be driven at such distances apart as will suit the size of the brush. Evergreen limbs and branches, especially those of Hemlock and Spruce, are the most effective. If plenty of stones are near, the space behind these stakes and walls of brush may be filled in with them. The effect of these obstructions is greatly to retard the current behind the brush work, but not to shut out the water altogether at first. This will cause the water to deposit sediment, and in time wholly cover the stones and inner bush, and form a new and solid bank. This will be helped very much by repeated deposits of brush and stones on the edge of the old bank, gradually extended out, until the further line of brushes reaches where the final bank is to be made. As the bank forms, it is well to plant willow stakes in it, which will root and grow, and the interlacing roots will hold the soil until it becomes firm and compact. When the final bank is reached, a permanent planting should be made upon it; the older trees cut down and the soil thus made seeded to grass. The work will then be kept permanent by careful protection of washing and strengthening the bank as may be needed. In the case of an abrupt bend, as at C, it would be well to cut off a part of the point and drive willow stakes across it, so as to form a more gradual bend, and by starting a cutting at the point to set the stream at work to finish its own repairing.

"The latter method mentioned (the reforming of the banks) may be done by cutting out a new channel across the neck of the bend in either of the directions shown by the doted lines in Fig. 59, as may be found

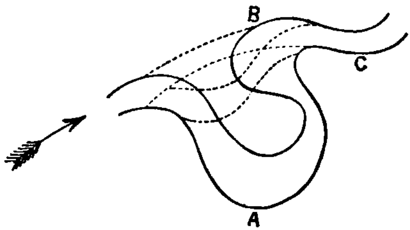


Fig. 59.

most convenient. The course of the new channel should be well studied out, and the beginning of it so placed with regard to the course of the entering current that the stream will be led easily into the desired direction.

"The old channel should not be closed altogether, but should be obstructed, as previously mentioned, so as to cause the stream itself to complete the work of closing it, which will be finally accomplished after a few successive floods. But these must be controlled in a proper manner, lest the work done through several years may be undone in a day."

The washing away of the river banks by the scouring or abrading action of the stream, may be prevented by proceeding in very similar lines to those above recommended for remedying such an evil. Stakes and brush may be planted at the edge of the stream where any portion of the bank is threatened, or a sufficient weight of stones may be piled up, with a good effect, giving the pile height and slope enough to withstand the flow of the river in times of flood. If the stream is not deep, in dry weather, the river will probably furnish a plentiful supply of stones for this purpose. Flat or oval-shaped stones, of a small size, resist the current better than large angular ones.

APPENDIX.

1.—Elkington's System.

Elkington, called the father of under-draining, introduced his system about 1764. His theory was, that water from springs was the cause of wetness in land; that the direction of the springs was to be ascertained, and then tap them by boring into them with an auger where they are below the depth of the ditch. Johnstone states that Elkington's principles depend chiefly on three things:—

1. Upon discovering the main spring, or source of the evil;
2. Upon taking the subterraneous bearings; and
3. By making use of the auger to reach and tap the springs when the depth of the drain is not sufficient for that purpose.

"The first thing, therefore, to be observed is, by examining the adjoining high grounds, to discover what strata they are composed of, and then to ascertain as nearly as possible the inclination of these strata, and their connection with the ground to be drained, and thereby to judge at what place the level of the spring comes nearest to where the water can be cut off and most readily discharged. The surest way of ascertaining the lay, or inclination, of the different strata is by examining the bed of the nearest stream and the edges of the banks that are cut through by the water, and any pits, wells or quarries that may be in the neighbourhood. After the *mainspring* has been discovered, the next thing is to ascertain a line on the same level to one or both sides of it, in which the drain may be conducted, which is one of the most important parts of the operation.

"*Lastly*, the use of the auger, which, in many cases, is the *sine qua non* of the business, is to reach and tap the spring, when the depth of the drain does not reach it, where the level of its outlet will not admit of its being cut to a greater depth, and when the expense of such cutting would be great and the execution of it difficult."

According to these principles, says Johnstone, this system of draining has been attended with extraordinary consequences, not only in laying the land dry in the vicinity of the drain, but also springs, wells, and wet ground at a considerable distance, with which there was no apparent connection.

2.—The Deanston System.

Thorough drainage was brought especially into notice by the late Mr. Smith, of Deanston, in Scotland, about 1832. His system briefly stated was as follows:—

"1. *Frequent* drains at intervals of from ten to twenty-four feet.

"2. *Shallow* depth, not exceeding 30 inches, designed for the single purpose of freeing that depth of soil from stagnant and injurious water.

"3. *Parallel drains at regular distances* carried throughout the whole field, without reference to the wet and dry appearance of portions of the field, in order to provide frequent opportunities for the water, *rising from* below and falling on the surface, to pass freely and completely off.

"4. *Direction of the minor drains*, 'down the steep,' and that of the mains along the bottom of the chief hollow, tributary mains being provided for the lesser hollows.

"The reason assigned for the minor drains following the line of deepest descent was, that the stratification generally lies in sheets at an angle to the surface.

"5. *As to material.*—Stones preferred to tiles and pipes."

3.—The Deep-Drainage System.

Mr. Josiah Parkes was the early advocate of deep drainage. As compared with the Deanston method, Mr. Parkes was in favour of :—

1. *Less frequent drains*, at intervals varying from twenty-one to fifty feet, *with preference for wide intervals.*

2. *Deeper drains at a minimum depth of four feet*, designed with the twofold object of not only freeing the active soil from stagnant and injurious water, but of converting the water falling on the surface into an agent for fertilizing; no drainage being deemed efficient that did not both remove the water falling on the surface and keep down the subterranean water at a depth exceeding the power of capillary attraction to elevate it to near the surface.

3. *Parallel arrangement of drains*, as advocated by Smith, of Deanston.

4. *The advantage of increased depth*, as compensating for increased weight between the drains.

5. *Pipes of an inch bore, "best known Conduit"* for the parallel drains.

6. The cost of draining uniform clays, he held, should not exceed £3 per acre.

4.—The Keythorpe System.

The peculiarities of the Keythorpe system of draining, as described by Mr. Trimmer, consist in this, that the parallel drains are not equidistant, and that they cross the line of the greatest descent. The usual depth is three and a half feet, but some are as deep as five and six feet The depth and width of interval are determined by digging trial-holes, in order to ascertain not only the depth at which the bottom water is reached, but the height to which the water rises in the holes and the distance at which a drain will lay the hole dry. In sinking these holes, clay-banks are found with hollows or furrows between them, which are filled with a more porous soil, as represented in the annexed sectional diagram.

The next object is to connect these furrows by drains laid across them. The result is, that as the furrows and ridges here run along the fall of the ground, which I have observed to be the case generally elsewhere, the submains follow the fall and the parallel drains cross it obliquely.

The intervals between the parallel drains are irregular, varying in the same field from 14 to 21, 31, and 59 feet. The distances are determined by opening the diagonal drains at the greatest distance from the trial-holes at which experience has taught the practicability of its draining the

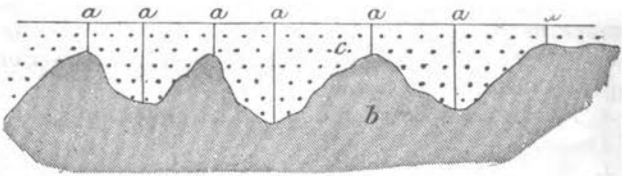


Fig. 60.

hole. If it does not succeed in accomplishing the object, another drain is opened in the interval. It has been found, in many cases, that a drain crossing the clay-banks and furrows takes the water from holes lying lower down the hill—viz. it intercepts the water flowing to them through these subterranean channels. The parallel drains, however, are not invariably laid across the fall. The exceptions are on ground where the fall is very slight, in which case they are laid along the line of greatest descent. On such grounds there are few or no clay-banks and furrows.

Judge French, in his work on drainage, says of this system: "It is claimed by its advocates that it is far cheaper than any other, because drains are only laid in the places where by careful examination beforehand, by opening pits, they are found to be necessary; and that is a great saving of expense, when compared to laying the drains at equal distances and depths over the field."

Against what is urged as the Keythorpe system several allegations are brought.

In the *first* place, that it is in fact *no system*. Mr. Denton having carefully examined the Keythorpe estate, and the public statements of its owner, asserts that the drains there laid have no *uniformity of depth*, part of the tiles being laid but 18 inches deep, and others 4 feet and more, in the same field.

Secondly,—that there is no *uniformity as to direction*; part of the drains being laid across the fall and part with the fall in the same fields, with no obvious reason for the difference of direction.

Thirdly,—that there is *no uniformity as to materials*; a part of the drains being wood, and a part tiles in the same field.

Finally, it is contended there is no saving of expense in the Keythorpe draining over the ordinary mode, when all points are considered, because the pretended saving is made by the use of wood, where true economy would require tiles, and shallow drains are used where deeper ones would in the end be cheaper. In speaking of this controversy it is due to Lord Berners to say, that he expressly disclaims any invention or novelty in his operations at Keythorpe.

5.—Air Drainage.

Mr. Hutchinson, in his "Practical Instructions on the Drainage of Land on Hydraulic and Pneumatic Principles," was the first to propound the theory of air drains.

"He digs a drain all round the *upper* ends of the system of drains which he has placed under and throughout the field, and this upper connecting drain is left open to the air, and so the stream of water through the drains is said to pull in a current of air through the pipes, and this is said to have a fertilizing effect upon the soil. We do not believe that any such effect will follow, for reasons which on 'hydraulic and pneumatic principles' seem to us sufficient. The fact is, that all drainage is 'air drainage;' and that, indeed, so far as the opening of a drain at its upper end to the air is effectual in facilitating the passage of water through it, there is to that extent a diminished right to claim on its behalf the results of air drainage. The air will then simply pour in at the upper end and pour out at the lower end, drawn along by the current of water through it, but not one particle of it will be of any use to plants. A drain is *receiving* at all its pores and cracks throughout its course. Nothing that is in it has any chance of getting upwards into the soil above it. Whatever enters will find its exit at the outfall; it has already done its work so far as the soil is concerned, and the sooner it is got rid of the better. That is the reason why drains are made straight down the hill. The air which does good to plants, is that which enters the surface of the soil and permeates both it and subsoil dissolved in the water which thus traverses both, or drawn in after it as it sinks. If the drain were full of water from top to bottom, then the whole weight of *that* water, as well as of what existed in the soil, would be helping to press onwards out of the soil, and helping to pull air in. If in such a case you facilitated the passage of water through the drainage tube, by opening its upper end, you would destroy the influence, whatever that may be, which the weight of water in the tube would exert in pulling air and water after it through the land. All that the water in the pipe would do in such a case, would be to pull in at its upper end and set it free at its lower end. We do not believe that the weight of water in the drainage tube has any effect whatever except in inducing its own escape. The true agent in the drainage of the land is the weight of water within the soil. Let that have a chance of making its escape below the subsoil, and it will draw air after it, and introduce an activity into the soil considered as a laboratory, which will tend much to its powers of feeding the plants growing within and upon it. The circumstance of the exit pipe being open at its upper end directly to the air, if influential, must, to the small extent of its power, diminish the activity of those passages within the soil from the air to that pipe along the whole course of its length, which alone (traversing the substance of the soil and subsoil) are usefully employed in feeding the soil-laboratory with reagents, or the soil-warehouse with food."—*Agricultural Gazette.*

6.—The Mole Plough.

The following letter, in reference to this implement, appeared in the *North British Agriculturist*, of August 3rd, 1882.

"Sir,—From your account of the Agricultural Show held at Reading, I see that Messrs. Fowler have exhibited a mole-draining plough, and as I have had some experience in using one of these with horse-power, and can testify as to its usefulness, I will give my reasons for first making a trial of one, and the result that followed. I had a deal of land drained according to a fashion that prevailed at one time, namely, 4 feet deep and 30 feet apart, and I need not say did not drain the land sufficiently. I then began to consider what could make the draining more effective; and having compared the naturally dry land with the land that required draining, I found that the bottom or subsoil of dry land was all drain, and to make wet land dry, one would have to imitate the dry land bottom as near as practicable. To do this I took one of Bentall's subsoils, put into it a coulter and a mole made of steel on the top of it. I then lifted a good deep furrow with a common two-horse plough, and put three horses in the mole-plough to follow. This I did transverse to the line of the drains, and in this way I made a drain about 18 inches deep in every furrow, and the drain was put in so deep that the tread of the horses did not injure them in the least. This had a most wonderful effect in drying the land, and if done with steam power, and to a greater depth, I have no doubt land could be dried to any extent; but care should be taken not to let the water too rapidly into the drains, for I have heard of some land drained by Mr. Smith of Deanston that was completely spoiled. He intended to make a thorough job, and put a tile in the bottom of the drains, then filled them up with broken stones to where the plough would reach; the consequence was the water went so fast it washed all the manure out of the soil.

"I have, however, no fear of the mole-plough having any such effect, for the ground will only be cut by the thin coulter, and the sides of the cut will adhere, so that the water can only percolate into the drain in a pure state, and so leave the manure in the soil.

"I wish Messrs. Fowler success with their mole-plough, for in these successive wet seasons the farmers require all appliances to keep the water from stagnating on the land to the permanent injury of their crops.—I am, &c., Dumfriesshire."

7.—Plug-Draining.

Plug-draining, like mole-draining, does not require the use of any foreign material, the channel for the water being wholly formed of clay to which this kind of drain, like that last mentioned, is alone suited.

This method of draining requires a particular set of tools for its execution, consisting of—first, a common spade, by means of which the first spit is removed, and laid on one side; second, a smaller-sized spade, by means of which the second spit is taken out, and laid on the opposite side of the trench thus formed; third, a peculiar instrument called a bitting-iron (Fig. 61), consisting of a narrow spade, three and a half feet in length, and one and a half inches wide at the mouth and sharpened like a chisel; the mouth, or blade, being half an inch in thickness in order to give the necessary strength to so slender an implement. From the mouth, on the right hand, a steel ring, B, six inches long and two and a half broad, projects at right angles; and on the left, at fourteen inches from the mouth, a tread, C, three inches long, is fitted.

A number of blocks of wood, each one foot long, six inches high, and two inches thick at the bottom, and two and a half at the top, are next required. From four to six of these are joined together by pieces of hoop iron let into

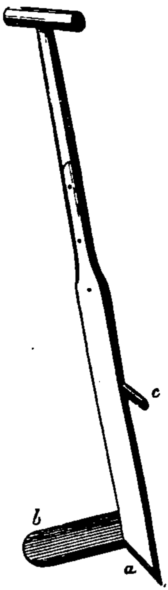
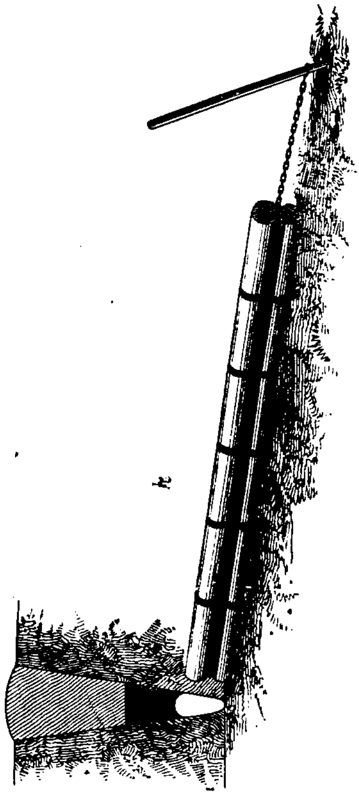


Fig. 61.



their sides by a saw-draught, a small space being left between their ends; so that when completed the whole forms a somewhat flexible bar, as shown in the cut, to one end of which a stout chain is attached. These blocks are wetted, and placed with the narrow end undermost, in the bottom of the trench, which should be cut so as to fit them closely; the clay which has been dug out is then to be returned by degrees upon the blocks, and to be rammed down with a rammer of wood three inches wide; as soon as the portion of the trench above the blocks, or plugs, has been filled, they are drawn forward, by means of a lever thrust through a link of the chain, and into the bottom of the drain for a fulcrum, until they are all again exposed except the last one (Fig. 62). The further portion of the trench above the block is now filled in and rammed, and so on the operations proceed until the whole drain is finished."—*Morton's Cyclopædia of Agriculture.*

8.—Drainage of Hill-Pastures.

"I consider," says the writer of a Prize Essay in the *Transactions of the Highland and Agricultural Society*, "that on hill-pastures it is desirable to allow the water-level to approach very near the surface, and that drains be only applied to remove an excess of water, with a careful regard to retain an ample supply of moisture for the continuous production of grasses. The objects to be attained are, to create for the sheep an improved pasturage, pure water, and a healthy atmosphere, which would allow of their being kept in greater numbers, and enable them to attain to a larger size and higher condition.

"Assuming that surface drains are most adaptable for hill-pastures, the size of the drain that combines most efficiency in proportion to its cost, for ordinary purposes, is 24 inches wide at top and 6 inches wide at the bottom, with a perpendicular depth of 16 inches. They should be cut clean, the turf-sod being placed 10 inches from the lower side of the drain, and the bottom clearings thrown beyond it; they will thus not be liable to be dragged into the drain. Direct-action drains (viz. those put in on the quickest descent) are most effective, and should be adopted on land of first quality: such land is generally indicated by the presence of Bull snout (tufted hair grass), Blue-point (tufted bog or blue-edge), Wild Scavy (devil's bit), Spart (blunt-flowered rush), and common rush: and any danger of such drains washing deep can be avoided by putting them in, not more than 9 yards apart, and not running them extreme distances ere they are delivered into main drains. The cost of such drainage is too great for poor or peaty surfaces, producing little but Stool-bent (goose-corn), Deer Hair (marsh spiked rush), Wire-bent and Flying-bent (blue-bent); but on such ranges, gentle declinating drains, at an angle that will allow a fall of 1 in 25, and placed 35 yards apart, may be applied with beneficial results. Flow-mosses abound in Drawling (hare's-tail cotton grass), and are benefited by having drains put in not less than 60 yards apart. These mosses require a full surface water-level, and drains at that distance will not do more than carry off the excess, whilst they will much facilitate the entry of sheep on to them, increase their scope over them, and aid their easy return to their lairs when satiated. Those drains should commence from those parts that present a sort of highway entry from the other lands; and the proper placing of the drain-sods will be here found of great importance, forming a sort of elevated platform very useful as a sheep-track, particularly in cases of snow. The important item of cost varies with the price of labour, and will range between 1*d.* and 2*d.* for 7 yards, and generally be found at 1½*d.* for that length."

9.—Drainage of Roads.

The reason that public roads remain muddy so long, till hundreds of passing waggons have cut the surface into deep ruts, is that there is no escape for the rain that falls upon them. One or more properly constructed under drains, extending lengthwise along the road, would afford a good remedy. In localities where gravel and small stones may be had the drainage may be made almost per-feet. The falling rain will pass through the gravel bed to the drain beneath nearly as fast as it falls, and no mud can be formed. When gravel and stones cannot be procured, the water will be longer in finding its way down, but the drain will nevertheless carry off the water in a much shorter time than when it has to escape by the slow process of evaporation.

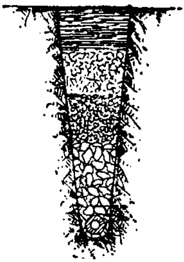


Fig. 63.

The best mode of constructing the drain is shown in Fig. 63. A good-sized pipe tile is laid at the bottom, surrounded by small stones. On these are laid smaller or broken stones or coarse gravel, then finer gravel, then soil or fine gravel at the surface. No free water can remain long on a road thus drained. A single drain in the middle of the track will often be sufficient, but for wider and more

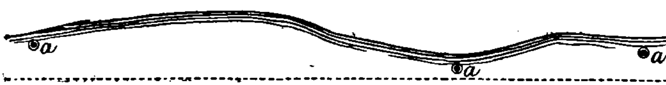


Fig. 64.

traversed roads it may be necessary to place two or even three parallel drains along the road.

Nearly all public roads have a more or less undulating surface, and outlets must be made at every depression for the discharge of the water from the tile to the roadside. Fig. 64 represents the line of the road over a curved surface of the country. The dotted line is a level. At A A and A are springs from the tile through which the water escapes, and is discharged into the natural channels which intersect the road.—*Albany Cultivator.*

10.—On the Making and Burning of Drain Tiles.

Extracts from a communication by Mr. Law Hodges, published in the Journal of the Royal Agricultural Society of England, Vol. V. Part II.:—

"Reflecting on these obstacles to universal drainage, where required, I conferred with Mr. John Hatcher (Brick and tile maker and potter, Beneden, Kent) on the possibility of erecting a kiln of common clay that would be effectual for burning these tiles, and of cheap construction —and the result was the building one in my brickyard in July last, and the constant use of it until the wet weather at the commencement of this winter compelled its discontinuance, but not until it had burnt nearly 80,000 excellent tiles; and in the ensuing spring it will be again in regular use.

"I shall now proceed to take in order the six points enumerated under the 9th head of the Prize Essays for 1845, as printed in the last volume of the Royal Agricultural Society's Journal, viz.:—

"1st. Mode of working clay according to its quality.
"2nd. Machines for making tiles.
"3rd. Sheds for drying tiles.
"4th. Construction of Kilns.
"5th. Cost of forming the establishment.
"6th. Cost of tiles when ready for sale.

"1st Point. Working the clay.

"All clay intended for working next season must be dug in the winter, and the earlier the better, so as to expose it as much as possible to frost and snow. Care must be taken, if there are small stones in it, to dig it in small pits and cast out the stones as much as possible, and also to well mix the top and bottom of the bed of clay together. It is almost impossible to give minute directions as to mixing clay with loam, or with marl when necessary, for the better working it afterwards, as the difference of the clays in purity and tenacity is such as to require distinct management in this respect in various localities; but all the clay dug for tile-making will require to be wheeled to the place where the pug-mill is to work it; it must be there well turned and mixed in the spring, and properly wetted, and finally spatted down and smoothed by the spade, and the whole heap well covered with litter to keep it moist and fit for use through the ensuing season of tile-making.

"2nd Point. Machine for making tiles.

"For the reasons already alluded to, I prefer Hatcher's machine. Its simplicity of construction, and the small amount of hand labour required to work it, would alone recommend it; for one man and three boys will turn out nearly 11,000 pipe tiles of 1 in. bore in a day of ten hours, and so in proportion for pipes of a larger diameter; but it has the great advantage of being movable, and those who work it draw it along the shed in which the tiles are deposited for drying, previously to their being burnt: thus each tile is handled only once, for it is taken off the machine by the little boys who stand on each side, and at once placed in the rows on either side of the drying-shed, thus rendering the use of shelves in the sheds wholly unnecessary, for the tiles soon acquire a solidity to bear row upon row of tiles, till they reach the roofs of the sheds on either side; and they dry without warping or losing their shape in any way.

"The price of this machine is £25, and it may be proper to add that the machine makes the very best roofing tiles that can be made, and at less than half the price of those made by hand, as well as being much lighter, and closer, and straighter, in consequence of the pressure through the die.

"It is necessary, in order to ensure the due mixing of the clay, as well as to form it into the exact shape to fill the cylinders of the machine, to have a pug-mill. Messrs. Cottam and Hallen make these also and charge £10 for them. This mill must be worked by a horse; in general one day's work at the mill will furnish rather more prepared clay than the machine will turn into tiles in two days.

"3rd Point. Sheds for drying.

"The sheds necessary for this system of tile-making will be of a temporary kind: strong hurdles pitched firmly in the ground in two parallel straight lines, 7ft. apart, will form the sides of the sheds, and the roof will be formed also of hurdles placed endways and tied together at the top, as well as to the upper slit of the hurdle, with strong tarred twine, forming the ridge of the roof exactly over the middle of the shed. They must then be lightly thatched with straw or heath, and the sharpness of this roof will effectually protect the tiles from rain. Two of these sheds,

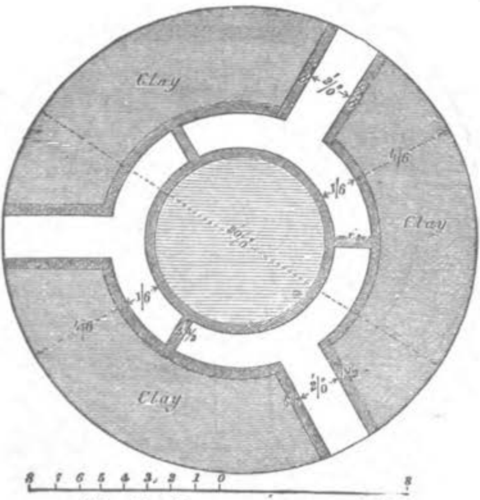


Fig. 65.—PLAN OF KILN AT A B.

each 110 ft. long, will keep one of the kilns hereafter described in full work.

"N.B.—These sheds should be so built as to have one end close to the pug-mill and the clay-heap, only leaving just room for the horse to work the mill, and the other end near the kiln. Attention to this matter saves future labour, and therefore money.

"4th Point. Construction of kilns.

"The form of the clay kiln is circular, 11 ft. in diameter and 7 ft. high. It is wholly built of damp earth, rammed firmly together, and plastered inside and out with loam. The earth to form the walls is dug out around the base, leaving a circular trench about 4 ft. wide and as many deep, into which the fire-holes of the kiln open. If wood be the fuel used, three fire-holes are sufficient; if coal, four will be needed. About 1,200 common bricks are wanted to build these fire-holes and flues; if coal is used,

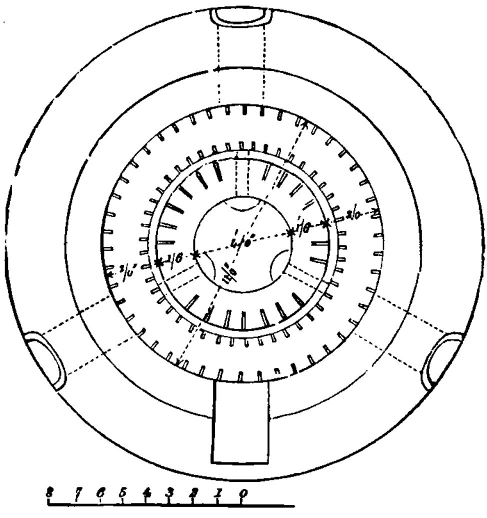


Fig. 66.—Plan of Top of Kiln.

rather fewer bricks will be wanted, but then some iron bars are necessary—six bars to each fire-hole.

"The earthen walls are 4 ft. thick at the floor of the kiln, are 7 ft. high, and tapering to the thickness of 2 ft. at the top; this will determine the slope of the exterior face of the kiln. The inside of the wall is carried up perpendicularly, and the loam plastering inside becomes, after the first burning, like a brick wall. The kiln may be safely erected in March, or whenever the danger of injury from frost is over. After the summer use of it, it must be protected by faggots or litter against the wet and the frost of winter.

"A kiln of these dimensions will contain—

47,000	1-in.	bore	pipe tiles.
32,500	$1\frac{1}{4}$	,,	,,
20,000	$1\frac{3}{4}$	,,	,,
12,000	$2\frac{1}{4}$	,,	,,

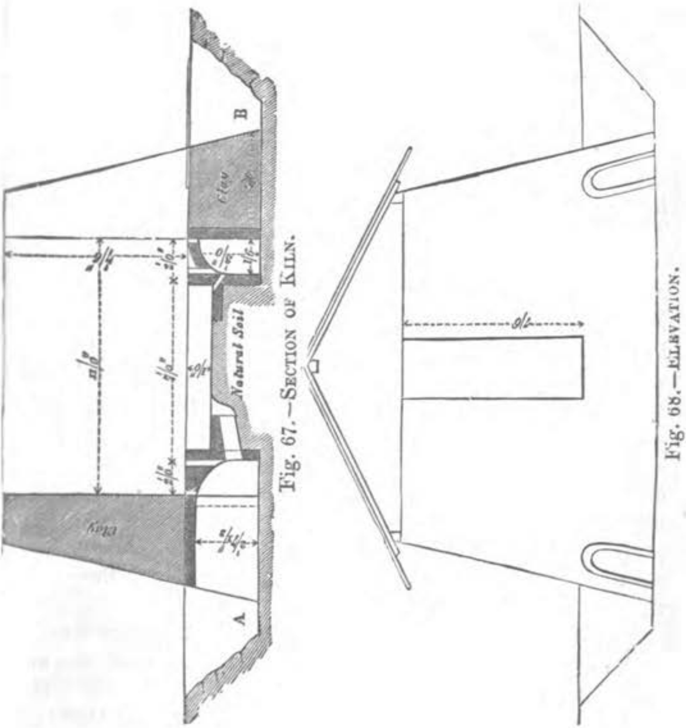


Fig. 67.—Section of Kiln.

Fig. 68.—Elevation.

and the last-mentioned size will hold the same number of the inch pipes inside of them, making therefore 24,000 of both sizes. In good weather this kiln can be filled, burnt, and discharged once every fortnight; and fifteen kilns may be obtained in a good season, producing—

705,000 1-in. pipe tiles.
Or 487,500 1¼ " "
Or 300,000 1¾ " "

and so on in proportion for other sizes.

"N.B.—If a kiln of larger diameter be built, there must be more fire-holes and additional shed room.

"5th Point. Cost of forming the establishment.

The price charged by Messrs. Cottam and Hallen for the machine, with its complement of dies, is . . .	£25
Price of pug-mill	10
Cost of erecting kiln	5
Cost of sheds, straw	10
	£50

(The latter item presumes that the farmer has hurdles of his own.)

"6th Point. Cost of tiles when ready for sale.

"As this must necessarily vary with the cost of the fuel, rate of wages, easy or difficult clay for working, or other local peculiarities, I can only give the cost of tiles as I have ascertained it here according to our charges for fuel, wages, &c. &c. Our clay is strong, and has a mixture of stones in it, but the machine is adapted for working any clay when properly prepared.

"It requires 2 tons 5 cwt. of good coals to burn the above kiln full of tiles. Coals are charged here at £1 8*s.* per ton, or 1,000 brush faggots will effect the same purpose and cost the same money; of course some clays require more burning than others; the stronger the clay the less fuel required.

"The cost of making, the sale prices, and number of each sort that a waggon with four horses will carry, are as follows:—

	Cost. *s.*	*d.*		Sale price. *s.*	Waggon holds—
1-in. pipe tiles . .	4	9	per 1,000	12 . .	8,000
1¼ " . .	6	0	"	14 . .	7,000
1¾ " . .	8	0	"	16 . .	5,000
2¼ " . .	10	0	"	20 . .	3,500
2¾ " . .	12	0	"	24 . .	3,000
Elliptical tile				. 24 }	2,000
Soles				. 80 }	

"All these tiles exceed a foot in length when burnt.

"The cost price alone of making draining tiles will be the charge to every person making his *own* tiles for his *own* use. If he sell them, a higher price must, of course, be demanded to allow for some profit, for credit more or less long, for bad debts, goods unsold, &c. &c.; but he who makes his own saves all expenses of carriage, and, as his outlay will not exceed £50, the interest on that sum is too trifling to be regarded, and he has no additional rent to pay; and after he has made as many tiles as he wants, his machine and pug-mill will be as good as ever, with reasonable care, and will fetch their value."

11.—Drain Pipe Machine.

Fig. 69 is an engraving of Armitage & Itter's Patent Horizontal Pipe and Tile Machine, which is manufactured by Barford & Perkins, Peterborough. The machine is of a very portable construction, is easily worked by a strong

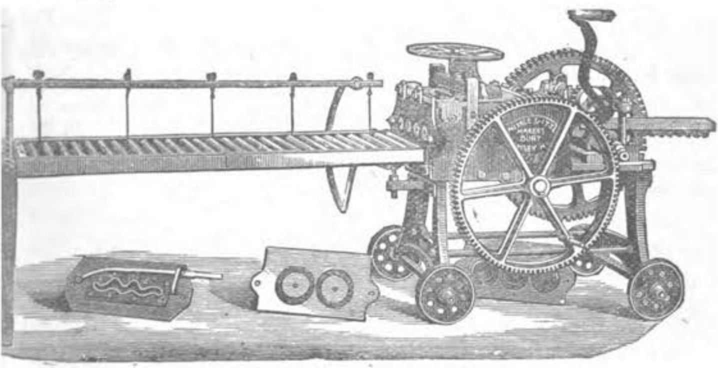


Fig. 69.

lad, and can be moved to and fro with little difficulty. The price of this machine, with long cutting table, and one pipe die of any size to 5 inches internal diameter, in cast iron, is £16 16s. The machine is also made in larger sizes at a slight increase in the cost.

12.—Data for calculating Rainfall.

Inches Depth of Rainfall.	Cubic Feet on an Acre.	Gallons on an Acre.
1	3,630	22,635
2	7,260	45,270
3	10,890	67,905
4	14,520	90 539
5	18,150	113,174
6	21,780	135,809
7	25,410	158,444
8	29,040	181,079
9	32,670	203,714
10	36,300	226,349

An inch of rain is roughly equivalent to 100 tons per acre.

An inch of rain per annum on an acre is roughly equivalent to ten cubic feet per day.

Annual depth of rain-fall in different countries and seasons ranges from 0 to 150 inches.

In Britain, different seasons and districts, 15 to 100 and upwards.

Ratio of available to total rainfall on gathering-grounds: steep impervious rock, from 1·0 to 0·8, moorland and hilly pasture, from ·8 to ·6, cultivated land, from ·5 to ·4, and sometimes less; chalk 0.

Greatest depths of rain in short periods: one hour, 1 inch; four hours, 2 inches, 24 hours 5 inches.

INDEX.

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SCOTT'S FARM ENGINEERING TEXT-BOOKS

II.

IRRIGATION AND WATER-SUPPLY

A

PRACTICAL TREATISE

ON

WATER-MEADOWS, SEWAGE IRRIGATION AND WARPING; THE CONSTRUCTION OF WELLS, PONDS, AND RESERVOIRS; AND RAISING WATER BY MACHINERY FOR AGRICULTURAL AND DOMESTIC PURPOSES

PREFACE.

The full advantages of irrigation are best realised in dry tropical or semi-tropical countries, where rain falls only at long intervals. There, many a large tract of land, that is naturally barren and worthless, is, with this provision, seen to yield rich and abundant crops. In these countries irrigation is a commercial necessity, and large sums of money are profitably expended on it.

In countries of Northern Europe, where the climate is humid and temperate, by far the largest outlay is incurred, not in irrigation works, but in draining lands which suffer from an excess of moisture. It can rarely be necessary, on such soils, except in periods of exceptional drought, to have recourse to the double and expensive process of subsoil draining followed by irrigation. Subsoil draining is in itself a protection against drought; and deep tillage and frequent hoeing and stirring of the surface soil are to some extent substitutes for rain, in the cultivation of plants. Still, in a climate like that of Britain, where the rainfall varies from 15 inches or less annually in dry districts in dry years, to 150 inches or more in wet districts in wet years, it would be strange if the extremes of drought and flood did not occasion, at different times and in different places, the need of irrigation as well as of drainage.

There are, indeed, few English farms that could not, in average years, with a good command of water for irrigating crops, be made to produce far more largely than they do, and that without incurring outlay upon costly engineering works. It is not very wide of the mark, perhaps, to affirm that English water-meadows are doubled in value by irrigation; and a good supply of water has been known to increase the value of arable land from four to ten fold.

But because the need of irrigation is not incessant, and because abundance of water is within reach of every farmer in this country, and can generally be drawn upon freely and without cost, the watering of crops in dry weather suffers unaccountable neglect amongst us. We have seen crops allowed to fail from drought, in situations where two or three furrows marked out by a plough, and connected with some neighbouring watercourse, could have been made the means of watering many acres of land.

In countries where irrigation is not such a casual necessity as it is in our own, the agriculturists are more careful to adapt their lands for it, though in most cases they have to pay dear for the water they use, and often also have to raise it, at great additional expense, to the elevation of the lands to be watered.

On small holdings, and especially in garden culture and upon market-garden farms, where the value of the produce is greater than in ordinary farming, the possibilities of irrigation, and the benefits of its practice, can scarcely be exaggerated, even in situations where considerable expense may be involved in obtaining and applying the necessary quantities of water.

Agricultural water-supply, however, involves much besides the watering of crops. With the live stock of the farm, the need of water is more urgent than for irrigation, and the dependence of live stock on artificial supplies is more incessant. Only those who have had experience in stock-keeping on a large scale, in regions where there is little or no rainfall during many months of the year, can realise the full importance of this part of our subject. Horses and cattle require on the average about five gallons each, and a sheep about half a gallon, per day, in dry weather. On waterless formations, therefore, any means of rendering water easily come at does much to enhance the value of the land for grazing purposes.

In the stock-yards, as in the pastures, a plentiful supply of wholesome water is a first necessity; yet what is the real state of matters in this respect, on many farms? A month's dry weather sees the water-supply exhausted; or cattle are compelled to drink from a dirty duck pond, or from some stagnant hole which is too often the main receptacle for sewage and liquid manure. Is it wonderful that animals compelled to drink such water are injured in health? that epidemics break out amongst them? or that milk from cows so treated is a source of danger and disease to the consumers of it?

The supply of water for agricultural engines is now only of secondary importance to the requirements of live stock; and water-power, for driving threshing and other machines, if not an absolute necessity, is certainly a great advantage in most situations. Every acre of land cultivated by steam requires about 100 gallons of water for engine use, and it is of much consequence that this supply should be accessible at every site likely to be occupied by the engines in cultivating an entire farm.

Most important of all, however, is the question of supplying the farmhouse and the cottages of the farm with abundance of pure water. Every adult consumes daily about half a gallon of water, and of course large quantities are required for domestic purposes beyond what is actually consumed in food and drink. The total daily requirements vary from about three gallons in cottages, to ten or fifteen gallons in large houses, for each person. Unless, at the same time, the water is good, a perfectly healthy condition of the body cannot be maintained. Many of the most dangerous forms of disease are known to be introduced into the system mainly through the agency of bad water. It is imperative, therefore, in the interests of health, that all "doubtful" waters should undergo a complete filtering process, which will not merely remove the grosser impurities but change chemically those in solution, before they are considered fit for drinking.

The various methods of irrigating land; of obtaining water by artificial means, and of storing and purifying it for use; of constructing wells, ponds, and reservoirs; and of raising water by machinery, are the subjects discussed at length in the following pages.

CONTENTS.

LIST OF ILLUSTRATIONS.

IRRIGATION AND WATER-SUPPLY.

CHAPTER I.

IRRIGATION.—THEORY AND EFFECTS.

IRRIGATION is the watering of land at will. And artificial watering is all the more effectual, as well as all the more easy of accomplishment, from the fact that the need of it is not incessant, but may generally be confined to a few months of the year.

There are few farms, perhaps, that it would be advisable, even were it possible, to lay wholly under irrigation: at the same time, there are few farms that, in average years, could not have been made to largely increase their crops had they had full control of the necessary supply of water.

On many farms which periodically suffer from drought, it is quite possible to control the water supply to a much greater extent than is done at present, and with the best results. Costly engineering works, by which water is conducted long distances for purposes of irrigation, are not practicable in general agriculture; yet many streams which now run by unutilized might be turned to account, and channels which now permit the escape of winter rains might, in many cases, be dammed with little expense, and the rainfall saved for irrigating the summer crops.

On the prairies the plans would sometimes have to be different, and the expense would probably be greater; but the results obtained would well reward the outlay. Where running streams and storage water were not available, tube-wells might be sunk at points where the water could be led across a vast plain, or down a valley, in irrigating streams and ditches, until it has been wholly absorbed by the soil. In California single wells are often made to irrigate sufficiently hundreds of acres, by the aid of a reservoir into which their waters are discharged when the soil does not require them, and there retained until the thirsty soil calls for irrigation.

Reasons for Irrigation.—Soils which do not contain more than 5 to 9 per cent. of moisture, Professor Church tells us, will yield none of it to the plant. Seeds, however, must absorb a very large quantity of water to induce germination. Young growing plants, also, require large supplies of water, and, indeed, all vegetable produce when in a growing state. The actual proportion is often 70 to 80 per cent., and sometimes as much as 90 to 96 per cent. The whole of this water is absorbed by the plant through the soil, and none of it directly from the atmosphere. When the daily evaporation from the leaves exceeds the amount of moisture the plant can take up by its roots, the plant must wither and die: in other words, it succumbs to drought.

Professor Johnson says: "The great deserts of the world are not sterile because they cannot yield the soil-food required by vegetation, but because they are destitute of water . . . . Poor soils give good crops in seasons of plentiful and well-distributed rain, or when skilfully irrigated; but insufficient moisture in the soil is an evil that no supplies of plant-food can neutralize."

The reason of this is obvious; for, in addition to the water which enters into vegetable composition, plants can only take up their food in a fluid condition. Lawes and Gilbert, at Rothamsted, proved that an acre of wheat in five months and eighteen days evaporated through its leaves 335¼ tons of water. Every drop of this water was more or less instrumental in transporting an atom of food from the soil to some part of the plant, and when the deposit was made, the water which was no longer needed passed off through the leaves.

The reasons for irrigation are summed up by Professor Church* as follows:—

"1. To make up for the absence of irregular seasonal distribution of rain, or for a local deficiency of rainfall.

"2. Sometimes a particular crop is irrigated because the plant is of an aquatic or semi-aquatic nature.

"3. To encourage early and rapid growth, by warmth of the water, or by the dissolved plant-food which it contains.

"4. That the land may be enriched and its level raised by means of the deposit from the water."

The third of these reasons, he points out, "is the determining cause of nearly all the artificial watering of land in temperate climates. It is not performed because the soil is dry and hot, for it is carried out mainly in the wettest and coldest months of the year. It is not performed because the crop to be raised is of

* "Encl. Brit.," 9th ed., art. Irrigation.

an essentially aquatic nature, for ordinary grasses and meadow herbage are principally watered. But it is performed that growth may be stimulated and fed through certain agencies which the water brings to bear upon the vegetation in question."

Effects on Soil.—"The immediate effect of irrigation upon the *consistence* of the soil is to soften it and render it more easily penetrable by the plough and by the roots of the plants. Hence, in dry climates, water is frequently applied before ploughing, at the rate of about 400 to 500 cubic yards per acre, or barely enough to loosen the earth to the depth of a foot without drenching it. But it is most important to observe that the ultimate effect of long-continued irrigation is to condense and harden the surface to a very inconvenient degree.

"Irrigation affects the *quality* of the soil by introducing into it common air and other gases, and vegetable and mineral matter held in suspension or solution by the water. In most cases the substances so introduced are beneficial to vegetation; but in some they are highly noxious. Even the water of large rivers sometimes, as has been observed in India, deposits on the surface, or introduces into the texture of the soil, salts, which in the course of time render it wholly sterile."

It likewise acts upon arable soil by facilitating the decomposition of soluble organic and inorganic matter contained in it, and carrying off such matter from it. The extent of this latter action is disputed; but it must be considerable, for constituents of vegetable growth have been found in under-drain water from cultivated fields; and large tracts of ground, impregnated with salts to such a degree as to make them incapable of cultivation, have been rendered fertile by washing with fresh water.

On undrained land, irrigation often injuriously affects the subsoil by charging it with water which stagnates in it, and renders it cold and sour to the roots of plants which descend into it.

It also exercises an important influence on the water-supply of lands lying at a lower level, by diverting from their natural channels streams which originally flowed through such lands; and on the other hand, by discharging upon their surface surplus waters from irrigated fields, or by saturating them with water, conveyed to them from such fields by subterranean infiltration. These effects are seen, not only in the soil itself, but in the diminished or augmented volume of spring and well water.

Finally, irrigation modifies the temperature of the soil beneficially or injuriously by communicating or abstracting heat, and by promoting evaporation from the surface, which is necessarily attended with some cooling of the ground.*

Effects on Vegetation.—Watering the soil promotes the germination of the seeds of cultivated plants, and, unfortunately, of weeds; and water is in, and of itself a necessary element of vegetable growth. Besides this, it is never quite free from extraneous matter, and it always contains, in solution or in suspension, foreign substances useful or injurious to vegetation. Hence, in climates and on soils where the natural supply of water is insufficient for the normal growth of plants, remunerative agriculture is impossible without artificial arrangements for procuring and administering it.

In many cases, however, although the quantity of

* Professor Johnson.

the product is increased, there is a deterioration in the quality of it. There is no doubt that all crops which can be raised without watering are superior in flavour and in nutritive power to those grown by the aid of irrigation. Garden vegetables, in particular, when profusely watered, are so insipid as to be hardly eatable. Comparative weight is, therefore, not always a true test: the heaviest potatoes, for example, are not the best.

"Moderate irrigation of herbaceous plants," says an Italian writer, "accelerates their germination and growth, but it checks the ripening of their seeds; and if water is applied in excess, it renders their texture less firm and substantial, and at the same time more subject to decomposition and waste."

Theory of Irrigation.—"Although," remarks Professor Church, "in many cases it is easy to explain the reason why water, artificially applied to land, brings crops or increases the yield, the theory of our ordinary water-meadow irrigation is rather obscure. For we are not dealing in these grass lands with a semi-aquatic plant like rice, nor are we supplying any lack of water in the soil, nor restoring the moisture which a plant cannot retain under a burning sun.

"We irrigate chiefly in the colder and wetter half of the year, and we 'saturate' with water the soil in which are growing such plants as are perfectly content with earth not containing more than one-fifth of its weight of moisture.

"We must look, in fact, to a number of small advantages, and not to any one striking beneficial process, in explaining the aggregate utility of water-meadow irrigation.

"We attribute the usefulness of water-meadow irrigation then to the following causes:—

"1. The temperature of the water being rarely less than 10° Fahr. above freezing, the severity of frost in winter is thus obviated, and the growth, especially of the roots of grasses, is encouraged.

"2. Nourishment or plant food is actually brought on to the soil, by which it is absorbed and retained, both for the immediate and future use of the vegetation.

"3. Solution and redistribution of the plant food, already present in the soil, occurs mainly through the solvent action of the carbonic acid gas present in a dissolved state in the irrigation water.

"4. Oxidation of any excess of organic matter in the soil, with consequent production of useful carbonic acid and nitrogen compounds, takes place through the dissolved oxygen in the water, sent on through the soil, where the drainage is good; and

"5. Improvement of the grasses, and especially of the miscellaneous herbage, of the meadows is promoted through the encouragement of some, at least, of the better species, and the extinction or reduction of mosses and of unnutritious weeds."

Drainage in connection with Irrigation.—Irrigation is only useful when the water is entirely at command, both to lay on and to take off at pleasure. Drainage is, therefore, a necessary preparation for irrigation.

Any want of good management on this point will entail loss and disappointment. This applies, not merely to the period of intermission which may be advisable between the waterings, but also, on stiff soils particularly, to the thorough under-drainage of the land.

It need not be feared that the thorough drainage of irrigated lands will do more harm than good by washing the most valuable constituents of plant food out of the soil. Phosphoric acid and potash, which are the most valuable components of soils and manures, Dr. Voelcker tells us, are retained in the land almost entirely; while lime, magnesia, sulphuric acid, chlorine, and soluble silica, the less important because more abundant and widely distributed mineral matters, pass into the water of land-drainage in considerable proportions. There may be a loss of nitrogen, however, if the land has been manured with a nitrate, and its application is immediately followed by irrigation. Still the good effects of drainage will always far more than compensate for any losses which may occur in this way.

Impoverishing Effects of Irrigation.—Water, as has been pointed out, stimulates production by its solvent action on the constituents of the soil and of manures. But for this very reason, prolonged irrigation is apt to become injurious, unless the water is rich, or unless adequate manuring, cultivation, and drainage attend its practice. In well irrigation especially, and also in canal irrigation, the water used is often of little fertilizing value, and unless it is rationally used, the results must be disappointing. For the first year or two after it is brought into play it will probably increase the crops; but without the concurrent application of the agencies already mentioned for maintaining fertility, it must eventually reduce the productive power of the soil.

This is exactly what has happened in certain districts of Upper India, where well and canal irrigation has been persisted in for years and generations even, without any attempt at sustaining fertility by the application of manures, or to lessen the impoverishing effect of the water by good drainage and cultivation.

"The real reason," says Colonel Corbett,* "of the falling off in the produce of canal-irrigated lands appears to be the consolidation of the pan by the treading of the cattle in ploughing, and the hardening of the upper soil in irrigation. This causes shallower ploughing, the roots of plants have less depth of soil in which to search for food, and cannot force their way into the hardened pan; and there is the alternate soaking and drying of the land, during which the natural salts of the earth are gradually brought nearer the surface by capillary attraction.

"This process may go on for some years before the lands show any excessive amount of *reh* on the surface; but the soil is steadily being poisoned by its accumulation near the surface, which accounts, together with the increased hardness of the soil, for the diminished fertility of lands some time under irrigation."

Influence of Tillage in mitigating Drought.—Hoeing and frequent stirring of the soil are good substitutes for rain. Those parts of the garden that are most frequently cultivated show the best results in dry weather. A deep, well-manured soil suffers much less from drought than a shallow soil. Under-draining also is a safeguard against drought. The course of the drains can easily be traced in a dry season by the ranker growth of vegetation above them.

Deep cultivation keeps the soil loose and open, and allows the water to sink into it and escape evaporation. In the case of deep cultivation generally, over a country, more especially a level country, there is a reservoir of water under every field sufficient to supply the wants of vegetation, held there by the soil itself.

A writer in the *American Agriculturist* states that

* "On the Climate and Resources of Upper India."

since some of the great plains of America have been broken up by the plough, a great amelioration of local climate has taken place. "As soon as the tough sod has been ploughed, and the soil been mellowed and made absorbent, the rain soaks into the ground instead of flowing off, and, percolating through the subsoil, supplies springs, which break out in low spots and furnish water for new rills and brooks. The atmosphere is no longer parched, but becomes moist, and its former extreme variations of temperature do not occur. The climate changes, and the moisture of the air and the consequent rainfalls are increased. A new circulation is established, and the storms and showers are those of a temperate instead of a torrid zone. Facts have shown that these conclusions are correct, and the observations taken in many places near the hundredth meridian, and eastward to the Missouri River, indicate a greatly increased rainfall, the increase amounting, in many cases, to several inches a year. Farmers no longer fear disastrous droughts, and there are few localities where their business is safer."

CHAPTER II.

PRACTICAL ADVANTAGES OF IRRIGATION.

In a climate like that of the British Isles, one can scarcely realise the full advantages which attend irrigation in tropical and semi-tropical countries. In California and Mexico, in Egypt and India, in parts of Southern France, Spain, and Italy, and elsewhere, where rain falls only at lengthened intervals, there are vast tracts of land, now contributing bountifully to the world's commerce and industry, that would be absolutely barren and worthless but for this provision.

In the South-western States of America there are many million acres of the most splendid land now lying idle and waste, unable to find purchasers at even nominal prices, because, without the means of irrigating and watering them, they are practically useless both for cultivation and for stock-raising. Yet the very same lands, which go a-begging at fifty cents an acre, in their natural state, when a supply of water has been brought to them, are eagerly purchased at $5,* $10, and even in some cases at $20, and upwards, per acre.

In Colorado, where land is of little value to the farmer unless water is assured, Mr. Pabor tells us that a quarter-section (160 acres) becomes worth at least

* 1 dollar = 4s. 2d.

$10 per acre when an irrigating canal has been built. Water has a commercial value of $15 per acre, when in the shape of a water-right, which is a perpetual claim upon a canal for a certain amount of water each year. When water is rented by corporations to consumers it has a yearly average value of $2 per inch, running continuously throughout the growing season, which amount is considered sufficient to irrigate one acre of grain land.

In Madras, taking an average of thirteen improvements, irrigation shows a net annual gain in revenue, after deducting all charges, of 134 per cent. per annum on the capital.

In Spain, unwatered land of the first quality sells for £32 per acre; when irrigated, the same lands bring £128 per acre. In the same country, second-class land, selling at £20 per acre, is at once increased in value to £100 per acre; third-class land, worth £12 per acre, is increased to £72; fourth-class land, worth £6 per acre, is increased to £60, when irrigated. A good supply of water thus increases the value of land from four to ten fold.

In Italy, the increase due to irrigation is also very great. Mr. Jackson puts it at 50s. on sandy soil, and at 40s. on clayey soils, per acre, annually; which is obviously an under estimate if these figures are meant to represent the increase of produce due to irrigation, but would probably be near the increased rental value.

In France, where irrigation is not an absolute necessity, as in Spain and Italy, it is generally considered that land is worth 50 per cent. more when it can be irrigated than when it cannot. In Vaucluse, according to Mr. Moncrieff, the rental of good land is about

£3 4s. unirrigated; if irrigated, it rises to about £4 3s. per acre.

In England, where irrigation is chiefly confined to the watering of meadows, the produce of grass is at least doubled by the operation. In favourable situations, and in good seasons, an irrigated meadow affords —(1) Early spring grass to feed stock, in particular ewes and lambs; (2) a good crop of hay; and (3) a good crop of after-math. A dry meadow of the same quality would only afford—(1) an inferior crop of hay; and (2) an inferior after-math.

It is not, perhaps, too much to assume that the meadow will be all the spring crop the better by watering.

To give these advantages a money value, it may be said that, in England, if a dry meadow of good quality is worth £2 per acre to rent, the same land, irrigated, will probably be worth £5 per acre.

Water meadows not only afford grass at an unusual season, and when most wanted, but the hay crop is more certain and larger; and the land requires no manure. These advantages may well be worth an additional £3 per acre on good land; while upon poor land the increase will be proportionately greater.

CHAPTER III.

CIRCUMSTANCES FAVOURING IRRIGATION.

Water Supply.—The first consideration, and one common to all lands, is the question of water-supply, and the possibility of applying that water, or a portion of it, for irrigation purposes.

Where water can only be procured by sinking or boring wells, or by storing rain or flood water in tanks and reservoirs—or where the lands are on a higher level than the source of supply, and the water has, consequently, to be raised by artificial means—the cost in either case may be greater than the profit to be derived; and under such circumstances irrigation will often be deemed impracticable.

Streams, where they exist, furnish the most ample and most economical supply of water. This is particularly the case when the water can be taken directly from the stream, and brought upon the field by a short conductor.

Springs are often advantageously situated for irrigating lower lands by gravitation, and will, as a rule, furnish more water than would be suspected. A continuous flow of 1 cubic foot of water per second, during twenty-four hours, is sufficient to cover four acres of land to a depth of nearly 6 inches. One such spring would, therefore, suffice to irrigate many fields, watering them alternately. Where several small springs occur near each other, connecting drains can often be put in, and the waters collected and brought into one channel.

Canals which serve for irrigation are frequently only conveyers of water from distant rivers, or from natural lakes. If a canal is formed with the express object of watering a given area of land, the capacity of the canal should be large enough to provide a flow considerably in excess of the actual quantity of water required. Where the water has to be carried a long distance, and the soil is porous, the loss by filtration and evaporation may amount to 25 and even 33 per cent.

Catch-water Tanks and Reservoirs.—In many cases where irrigation is carried on, the supply of water is obtained by impounding the winter rainfall for use during the dry season. The flood-water, in very dry districts even, when stored and made available at the right season, is found amply sufficient for the production of good crops.

Assuming that an inch of water is the least quantity that should be applied at each watering, this, over one acre of surface, is equal to 3,630 cubic feet, or 27,152 gallons. To irrigate 30 acres once, at this rate, would require a tank capacity of 108,900 cubic feet, or a tank exactly ¼ acre in extent and 10 feet deep; and to irrigate 30 acres four times, or 60 acres twice, would require a tank four times as large, or 1 acre in extent and 10 feet deep.

A tank or reservoir can often be formed by merely erecting a dam or embankment to impound the water in a natural basin or ravine. Indeed, it will seldom pay to make a ground-tank where the impounding basin has to be wholly excavated. A tank 1 acre in extent and 10 feet deep contains 16,133 cubic yards of earth, measured in place; and this cannot, under the most favourable management, be removed for less than 2d. per yard, or £134 8s. 10d., and generally the cost will reach 4d. per cubic yard, or even more. Even at the smaller sum the outlay would be even £4 10s. per acre for 30 acres; and there are few cases, perhaps, where it would pay a tenant farmer to incur that expense, although the improvement would be permanent, and would ultimately, no doubt, repay itself.

Wells.—Where no better method of procuring water can be devised, wells may be resorted to. The great objection to wells, however, is not merely the first cost, but generally the after-expense of raising the water.

Artesian wells are often recommended as a source of water for irrigation; but they cannot always be depended upon for this purpose, as few of them can yield an adequate supply of water. At the best "wells can only be depended upon for such a small supply as would serve to irrigate a garden or small market farm, where the large value of the crops admit of raising water for a lengthened season, and storing it in reservoirs for use in emergencies. The idea that artesian wells may be made a source of supply for completely irrigating large tracts of land, if ever held by over-sanguine persons, must be abandoned. For partial irrigation they may be made available; but the quantity of water needed for the irrigation of a few acres of land only, in localities where there is no summer rainfall, as upon our western plains, is far beyond the capacity of any artesian well to supply, unless it be one of extraordinary volume.

"Not long ago the *Scientific American* editorially announced that one artesian well would supply a farm of 640 acres upon the plains with water for irrigation, and would also form a nucleus for many large stock farms.

"The late Horace Greeley, who, although an enthusiast upon this subject, was more nearly correct, thought one artesian well would serve to irrigate a quarter-section of land, or 160 acres.

"An artesian well, 6 inches in diameter, would give a stream of 28 square inches, and would deliver 32 quarts per second, if the flow were at the rate of 4 miles an hour.

"Such a well would furnish an inch of water per day for 28 acres, or an inch a week for 196 acres, which would be a very insufficient quantity to irrigate dry open soils in places where the climate is arid.

"The cost of such a well would be at least $5,000 to $10,000, or more than the value of the land when irrigated." *

It will be seen from what follows in another chapter that these estimates of the capacity of artesian wells are far short of the results actually obtained by sinking wells in Australia and elsewhere. Tube-wells, too, can be put down at a comparatively trifling expense, compared with the outlay which has in many cases been incurred in sinking artesian wells.

The multiplication of wells in any district, it need scarcely be remarked, has the effect of lowering the spring level. This creates a necessity for deeper wells, causing the water to be raised from a greater depth, and entailing more expense.

Use of Drainage Water for Irrigation.—It will sometimes happen that drainage water can be utilized for

* Stewart, "Irrigation for the Farm, Garden, and Orchard."

irrigation purposes; but we by no means advocate the theory sometimes advanced that drainage is imperfect unless accompanied by irrigation. We do not admit the general truth of the proposition that on wet soils it is necessary to have recourse to the double and expensive process of deep draining, followed by irrigation. There is, doubtless, a certain medium depth of drain, dependent of course on the nature of the soil and subsoil, which will remove the excess of moisture in wet weather, as from a sponge saturated with water, and yet retain, like a damp sponge, sufficient moisture for the purpose of vegetation in dry weather. This object, as already explained, may be greatly promoted by deep and frequent cultivation. When the drainage water from high lands can be used in irrigating lower lying lands which are naturally in want of moisture, it may be done with advantage.

Situation.—The lands that admit of irrigation with most success are such as lie in low situations on the borders of rivers, or in sloping directions on hill-sides, where a command of water can be obtained from higher ground. The latter may often be irrigated more profitably than the former, for they are usually less productive in their natural state; while they can be watered at less expense for laying out the ground and with a less quantity of water. In tank or well irrigation, or where there is an impounding reservoir, the situation of the lands to be watered is comparatively immaterial, provided the source of supply is at a higher level.

Soil.—The soils best adapted for irrigation are those of a light and porous nature, such as sands and gravels. Clay soils, and also peat soils, are not so often benefited by it, except in dry and tropical climates, where the nature of the soil is of less importance than the ability to give it an artificial watering in seasons of drought.

These remarks, of course, have reference more particularly to the surface soil. A retentive surface soil prevents percolation, favours evaporation, and cools the land, which are serious disadvantages in irrigation; while a retentive subsoil, underlying a porous surface soil, may be a great advantage in dry climates, as it economises water.

Heavy or clay soils must always be thoroughly under-drained before they can be successfully irrigated. They will also be farmed with most profit when laid down in pasture, for irrigation adds considerably to the labour and difficulty of working them.

The relations of soils to water are extremely various, as will appear from the following table :—

	Percentage of water absorbed.	Percentage of water evaporated.
Loose sand	25	88·4
Ordinary clay soil . . .	40	52·
Loamy soil	51	45·7
Strong clay soil	61	34·6
Garden soil . . .	89	24·3
Peat	181	25·5

M. Debay classifies soils for irrigating purposes under three heads: (1) *Sandy Soils*; (2) *Argillaceous Soils*; (3) *Marshy Soils*. Of these he gives the highest value to sandy soils, the best being a clayey sand, warm, dry, and having some portion of marl in its composition. The finer the grain of the sand, the better adapted is it to irrigating purposes. One feature connected with the irrigation of sandy soils is, the abundance of reeds and rushes which they will produce when first placed into water; but these will gradually disappear as the plants of a higher class of vegetation increase. Of the argillaceous soils it may be said that the more tenacious and impermeable they are, the worse adapted are they for irrigation; and in such cases, where irrigation is adopted, deep drainage and deep cultivation are most essential. Marshy soils are the least valuable of all for irrigating purposes; but when well drained and managed they are capable of large yields.

Climate.—The success of irrigation depends in a great measure on the climate. It answers better in a dry climate than in a moist one, and where heavy wet seasons alternate with severe droughts, it will only be beneficial in the dry seasons. It will also be more profitable in a mild and genial climate than in one less propitious; as under the former circumstances it will not only afford more ample crops, but also a greater number of them, and more certainty of turning them to good account.

Where the climate is fine, irrigated meadows, for example, will yield three crops; first an early and valuable pasture for ewes and lambs; next a crop of hay; and, latterly, an after-math or good pasture.

In less favourable situations, only two crops can be obtained—one of hay and one of pasture; and neither of them so rich, nor so capable of being turned to great profit.

The question of rainfall is here, of course, all important; and not merely the amount of annual rainfall, but its distribution over days and weeks at various periods of the year.

Crops adapted for Irrigation.—Almost any crop may be raised by irrigation, but some plants flourish better under it than others, as the object and purpose of irrigation is merely to supply the natural wants of the plants, and not to stimulate them to an undue or excessive growth. The careful irrigator will study the wants of the plants he grows, and also the character of the soil he cultivates.

In our own temperate and humid climate, and in various other countries of Northern Europe, grass meadows seem to be most benefited by irrigation; but in warm Southern Europe, Egypt, India, and other parts, irrigation is chiefly applied to arable lands and crops. It is worth noticing, perhaps, that while in the latter countries irrigation is a commercial necessity, and large sums of money are profitably expended on it, in the former countries, where the climate is humid or temperate, by far the largest outlay is incurred, not in irrigation works, but in artificially draining lands which suffer from a superabundance of moisture.

Of all the cultivated grasses and leguminous plants, rye-grass and lucerne are the two which yield the best results under irrigation. The different species of cabbage, beet, and turnip thrive well with occasional waterings; as do also grain crops, up to the period of inflorescence, after which watering becomes injurious to them, except for a very short interval when the grain is filling.

Many of the plants cultivated for industrial purposes cannot well be grown without artificial supplies of water at certain times. Too much water injures them; yet much of their success depends on their receiving a regulated abundance of moisture. Madder (*Rubia tinctorum*), the sugar-cane (*Saccharum officinarum*), and

Clear water, especially if it proceeds from a spring in the same field, produces early and plentiful grass, but not of a good quality; and the land remains unimproved after many years' watering. We have seen the same unsatisfactory result where meadow irrigation was commenced by drawing water from a stream which has its source in the overflow of a lake. The stream is too pure for this purpose, leaving the richer particles in the lake whence it flows. The water, when first applied to the meadows, had the effect of eradicating moss, and helped to decompose waste vegetable matter; and it, therefore, for a time acted as a stimulus with seeming advantage. But when the meadows were annually mown, without an occasional top-dressing, the system in the end produced comparative exhaustion. It must be the same in many other places, where there is no extraneous matter in the irrigating stream, and where irrigation is begun without attending to local circumstances.

Thick and muddy waters, which convey along with them a rich and nutritive top-dressing and deposit it on the land, are productive not only of temporary but of permanent improvement, enriching the soil itself as well as the immediately following crop. In Southern France, Mr. Moncrieff* tells us, the difference between the meadows irrigated with the silt-bearing waters of the Duranee canals, and those of the clear cold Lorgues, is so marked that cultivators prefer to pay for the former ten or twelve times the price demanded for the latter.

Artificial richness is sometimes given to waters used for irrigation, as when the water is taken from the very bottom of a stream in order to carry as much

* "Irrigation in Southern Europe."

sediment as possible along with it on to the land, or where the drainage of sewers is conducted into the irrigating channel. Sewage irrigation, liquid manuring, and the use of light manures dissolved in water, offer the same advantages in a fuller degree, and will be dealt with in more detail farther on in this work.

River waters,—especially such as carry much suspended matter, and such as have received town sewage, or the drainage of highly manured land,—are more suitable for irrigation than water from tanks, wells, or springs. Streams in which fish abound are always considered good for irrigating with. "Hard" waters are also considered better than "soft" waters; this hardness being due to the presence of sulphate and carbonate of lime and magnesia, ingredients which are highly favourable to fertility. It is for this reason that water coming from the chalk formation is so good for irrigation purposes. So again with the water that comes from a granite formation, for it is rich in potash.

Water from forests, moors, and peat bogs, or from gravel or ferruginous sandstone is, as a rule, of small utility so far as plant food is concerned. Water containing much hydrous oxide of iron is generally considered very bad for irrigation; yet Sir John Sinclair tells us that the famous Presley bog in Bedfordshire is strongly impregnated with iron, and that even the water used to irrigate it is partially affected by it. Running water from mines is highly inimical to vegetation; and amongst other injurious sorts of refuse which can find their way into irrigating streams, are the chemical wastes from mills and factories in which the processes of dyeing, paper-making, metal-working, &c., are carried on.

Chemical analysis is the most satisfactory test of the quality of a water before it is used in irrigation; but some estimate of its probable effects may be formed by observing the natural products, the grasses and other plants, that grow on the banks and borders of the irrigating stream. We do not pretend to give a list of the particular plants which will afford this criteria of excellence in every place, for they will be found to vary with the soil and climate; but every farmer knows the plants which in his district will afford this indication of quality in the water used to irrigate with. "As a rule," says Mr. R. Scott Burn, "the water is of excellent quality if water-cresses (*Nasturtium officinale*), the aquatic ranunculus (*Ranunculus aquatilis*), grow near it; or other plants, such as the pond weeds (*Potamogeton perfoliatus*, or *P. fluitans*), and the speedwells (*Veronica anagallis*, or *V. Beccabunga*). The following plants grow in the neighbourhood of water of middling quality: *Sium cutifolium*, *S. angustifolium*, the mints (*menthæ*). If no plants are observable save the mosses and the sedges (*Carex acuta* and *C. stricta*), the quality of the water may be considered as bad."

Quantity of Water required.—On this point it is impossible to lay down any rule, as the quantity of water required for irrigating land so much depends on the climate, the nature of the soil, the object of watering, and the crop grown.

The more arid the climate, the greater of course the demand for water.

The composition and texture of both the super and subsoil greatly influence the amount of water required. M. Gasparin states that a soil containing 20 per cent. of sand needs irrigation once in fifteen days, while with 80 per cent. of sand it requires irrigation once in five days. A gravelly or sandy subsoil will allow of almost unlimited percolation; whilst, if it be clayey and retentive, percolation is reduced to a minimum.

The object of irrigating may be merely to make up deficiencies of rainfall and provide sufficient moisture in the soil for the support of a crop; or it may be for the sake of depositing on the land the fertilizing matters which are conveyed by the water. If the latter is the object in view, very large quantities of water may have to be used to produce the required effect.

In Northern Europe, for example, where irrigated meadows are common, large quantities of water are allowed to flow over the fields; the principal object being to manure the land by the sediment thus deposited. In the warmer climates of Southern Europe, India, &c., on the other hand, irrigation is only used to moisten the ground, and to supply by artificial means the want of rain, which is so much felt at times in those countries; and thus it is that the watering which would be effectual in the latter case would be deemed altogether insufficient for the water-meadows of Northern Europe.

Peculiarities of climate and soil, together with the object of watering, will generally have more influence on the amount of water required for irrigation than the kind of crop grown. Nevertheless some crops call for very much larger supplies than others.

The crops watered are usually classed in the following order, with regard to their special treatment and the amount of water they require:—

1. Grass meadows.
2. Lucerne, rye-grass, and other cultivated forage crops.
3. Cabbage, turnips, &c.
4. Beans and peas.
5. Wheat, oats, barley.
6. Sugar-cane, tobacco, indigo, madder.
7. Rice.
8. Gardens and fruit-grounds.

The quantity of water supplied during the season—which in Europe is only about six months in the year, say from April to October—to ordinary ploughed or hoed field crops varies from 20 to 40 inches. In the rice fields, of course, this amount is vastly exceeded; as it is also in the water meadows and many other grass grounds. The proper quantity, as well as the season for applying it, must necessarily vary under any particular soil and climate.

A flow of water, equal to 1 cubic foot per second, will cover 4 acres to a depth of nearly six inches in twenty-four hours; and, continued one hundred days, it will cover 400 acres to the same depth, or 200 acres with 12 inches of water. A cubic foot of water per second throughout the season has been found sufficient to irrigate from 30 to 90 acres of rice, according to the rainfall of the district.

Moncrieff gives the following table, by M. Conte, showing the acreage of each crop watered on the St. Julien Canal, and the amount of water required for each, as a fair specimen of the irrigation of Southern France:—

—	1. Surface watered. Acres.	2. Percentage borne by each to the whole.	3. Number of acres of each, irrigable per cubic ft. per second.	4. Quotient of column 1 by column 3. Discharge in cubic ft. per second.
Gardens	1183·9	16·	28	42·6
Meadows . . .	789·3	10·8	70	11·3
Lucerne grass . .	592·	8·	70	8·4
Beans	690·6	10·2	50	13·8
Madder	394·6	5·3	168	2·3
Chardon	296·	4·	184	1·6
Sundry other crops	3340·1	45·7	454	7·3
Total . .	7286·5	100·	—	87·3

The table gives a mean duty of 83·4 acres watered during the six months of irrigation, per cubic foot per second. But, as Mr. Moncrieff points out, the large area classified as sundries makes this result of little value, many of the crops included in this area being only watered in an emergency, and not regularly, like some of the other crops. If, for example, a vineyard is looking drooping, or a field of wheat turning prematurely yellow, it gets a watering. In cases of great droughts, wheat is occasionally watered as many as three times.

The meadows are watered from about every seven tc about every fifteen days, and yield three crops in the season. Lucerne grass is irrigated about as often as the ordinary meadows, is cut every month, and yields five or six crops during the season. Beans are irrigated every five days. Madder is not often irrigated more than three or four times after being planted out, the last time being immediately before it is dug up.*

In Piedmont and Lombardy, Mr. Jackson tells us,† one cubic foot per second waters 50 to 100 acres of grass land, or only 40 acres of rice. In the Madras Presidency, and in the North-west provinces of India, one cubic foot per second waters, in ordinary seasons, 100 acres of rice, or other very wet cultivation; in very dry seasons 50 acres. The highest duty actually performed in Central India is about 270 acres per cubic foot per second.

The following tables, by Mr. Jackson, furnish some useful details in regard to Italian irrigation :—

* Moncrieff, "Irrigation in Southern Europe."
† "Hydraulic Manual." (Crosby Lockwood & Co.)

I.

—	Absorbed.		Utilised.		Expended.	
	Meadow.	Arable.	Meadow.	Arable.	Meadow.	Arable.
Volume of water in cubic ft. necessary per acre at each watering	5885	8476	9160	9697	15045	18173

II.

—	Meadow land.		Arable land.	
	Watering once in 7 days.	Watering once in 10 days.	Watering once in 14 days.	Watering once in 20 days.
Quantity of continuous water in cubic feet per second per acre necessary for irrigation	·02486	·01740	·01501	·01005

III.

—	Meadow land.		Arable land.	
	Watering once in 7 days.	Watering once in 10 days.	Watering once in 14 days.	Watering once in 20 days.
Area in acres that can be irrigated by one cubic ft. per second	40·23	57·47	66·66	99·16

IV.

—	Area in acres.	Sandy soil.	Clay soil.
Supply necessary for each acre of the irrigable area . . .	1·00	·01346	·00924

"Result adopted for calculation of supply to 1 acre: in sandy soil, ·01346 cubic ft.; in clayey soil, ·00924 cubic ft."

"In Table I. the quantity of water sufficient for one irrigation or watering is taken at 15,045 cubic feet for meadow and 18,173 for arable land. It cannot be doubted, by any one conversant with irrigation in India or Spain, that this quantity is excessive.

"The object of ordinary irrigation in hot climates is simply to supply the place of rain and soften the soil, and differs much from the irrigation of lands in colder regions, which, partaking of the nature of sewage irrigation, has for its object the deposition of a fertilizing sediment rather than a supply of moisture.

"This latter description of irrigation being excluded from the project and data under consideration, the former alone has to be dealt with; and for such purposes, in India and in Spain, a watering of 10,000 cubic feet is ample, either for pasture or arable land. One such watering represents a depth of ·23 feet over an acre, and is equivalent to a continuous supply throughout the year of ·000317 cubic feet per second.

"In a hot climate, or with a drier soil, a greater number of waterings might be required, but not a larger supply at each watering."

From the foregoing tables the number of waterings appear to be forty-six and twenty-three in the year for meadow and arable land respectively on sandy soils, and thirty and fifteen on clayey soils. "Leaving out of consideration the fact that these waterings are a half and three-quarters larger than would be requisite in India or Spain, their number seems excessive.

"In India the number of waterings prescribed on the Nageenah Canal, North-west Provinces, is thus:—

For fruit-gardens	8	per annum.
„ hemp	5	per crop.
„ rice, indigo, sugar, tobacco, grass, herbs	4	„
„ cotton, wheat, barley, grains, and pulses	3	„

"In Spain the number of waterings in the year generally necessary are :—

For corn, flax, potatoes, olives, and pines .	6	waterings.
„ meadows and artificial grasses . .	8	„
„ garden produce	20	„

and these by no means show the highest duty obtained by water in Spain; for gardens on clayey soils are irrigated with ·0014 cubic feet per second per acre through the year, and only require double or treble that amount, say ·004 cubic feet per second, in very dry seasons; whereas the watering of garden land with twenty irrigations, as above, requires ·012 cubic feet." *

The assessment of the water rate is made in three different ways:

1. By fixed outlet, or by measurement.†

"The small channel of supply being constantly full and of a certain section, may be charged at so much per square inch or square foot of section, independently of the amount of pressure, for a certain time, as the day of 24 hours. This has been adopted in Italy, but has not been found to work well.

"A further development of this method is to measure by module all the water as distributed, a mode more

* Jackson, "Hydraulic Manual."

† There are three methods of measuring the discharge of a stream:—

1. By weir-gauges (for small streams) with notch orifice. The right-angled triangular notch is the best form of orifice, as it measures large and small quantities with equal precision, and has a sensibly constant co-efficient of construction. When orifices are wholly immersed, round or square holes are the best, because their co-efficients of construction vary less than those of oblong holes.
2. By current meters, in which the rotations of a fan driven by the current are registered by wheel-work.
3. By calculation, from the dimensions and declivity. Weeds have been known to increase friction tenfold.

likely to be adopted at present, now that modules are less expensive and more effective than formerly.

"2. By the area of land irrigated, or by crop.

"3. Water distribution by rotation.

"An irrigating channel of fixed dimensions, giving a constant fixed discharge, passes through the lands of several proprietors; a period of rotation is fixed for this channel, from 6 to 16 days, according to the crops. Each landowner can then have the whole volume of the channel turned on to his land once in the total period of rotation for a certain number of hours, as from 2 to 40, or 50, according to the amount of land he owns.

"For example. Let 10 days be the period of rotation, and let him require 12 hours' supply once in that period. His name is placed on the list, say sixth, and he gets his supply turned on at a fixed hour, and turned off at a fixed hour also. If the channel gives 20 cubic feet per section, his amount of water is equivalent to a continuous discharge of—

$$\frac{20 \times 12}{240} = 1 \text{ cubic foot per second.}$$

In this way intermittent supplies admit of mutual comparison."*

* Jackson, "Hydraulic Manual."

CHAPTER V.

MODES OF IRRIGATING.

THE mode of laying on the water must depend on the configuration of the surface, and on whether the land is under grass or tillage.

The systems that deserve to be specifically noticed are —Bed-work Irrigation; Catch-work Irrigation; Sub-Irrigation; Side-Irrigation with open Drains; Pipe and Hose Irrigation; Irrigation by Surface Pipes; Flooding, or Swamp Irrigation; Sewage Irrigation; and Warping. The three last-mentioned systems will be dealt with separately, however, in future chapters. Water-drills, carts, sprinkling-pots, and syringes ought also to be mentioned.

Bed-work Irrigation.—This system is only suitable to grass lands of a level or nearly level surface. It consists in laying out the ground into sloping beds or ridges, 10 or 12 yards wide, according to the nature of the soil, having their upper ends lying in a gentle slope from one end to the other of the meadow (Fig. 1). The main feeder or conductor is taken out of the river or canal, as the case may be, at a sufficient level to command the upper ends of these ridges. From this conductor the water is carried by small trenches or irrigating channels (*a*) along the tops of the ridges. These irrigating channels, or distributors, are made 4 or 5 inches deep, and 12 inches or more wide at their junction with the main conductor, the width gradually lessening as they recede from it. When the distributors are filled, the water overflows on both sides, and is taken up by the furrows or drains (*b*) which occupy the hollows between the ridges. The water thus collected by the furrow drains is received by the main drain, which conveys it back to the river from which it was taken, or carries it on to water other meadows, or other parts of the same meadow below. The main drain is, of course, cut across the lower ends of the beds, and requires to be

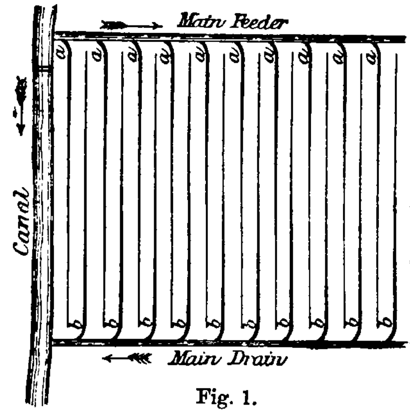


Fig. 1.

Fig. 2.

made nearly as large as the conductor. Fig. 2 shows a section of the bed-work.

The dimensions and inclination of the conductor and distributors should be so regulated to the water-supply that the beds can be wholly laid under water to the depth of about 1 inch. The conductor must be tapered off towards its farther end, in order that the diminished supply of water may still overflow; and the distributors must likewise be made to taper towards their farther extremity, both for the purpose of retarding the velocity of the water and of preserving a continuous overflow along their whole length. On the other hand, the small drains and the main drain should gradually widen towards their lower extremity. The distributors and small drains are usually made from 12 to 18 inches wide at their junction, and from 6 to 9 inches at their ends. The inclination of the ridge itself should afford a fall of 1 in 500, and the inclination of the sides of the ridges may vary from 1 in 100 to 1 in 1000, according to the retentive power of the soil. Ridges should not be more than 100 yards long.

Few if any meadows are now laid out on the bed-work system, as it is only applicable to flat meadows, which can generally be rendered productive without the sacrifice of land which is involved in throwing them up in ridge and furrow form, and cannot be carried out without very considerable expense, the cost of the work often ranging from £10 to £20 per acre.

Louden gives an example of a very complete piece of bed-work irrigation (Fig. 3), which was formed for the Duke of Bedford, by Smith, at Priestley, on a meadow of irregular surface. The water is supplied from a brook (*a*), to a main feeder, with various ramifications (*b b*); the surface is formed into ridges (*c c*), over which the water flows, and is carried off by the drains (*d d*) to the main drains (*e e*), and to the brook at different places (*f f*). There are bridges (*g*) over the main feeders, small arches over the main discharging drains (*h*), and three hatches (*i*).

Formation of Water Meadows on the Bed-work System.—Sir John Sinclair gives the following particulars on this point: "The water being carried with a proper fall—that is, with from 1 inch of fall in 20 yards to 1 in 30 yards, according to the weight and velocity of the water above the mouth of the conductor—to

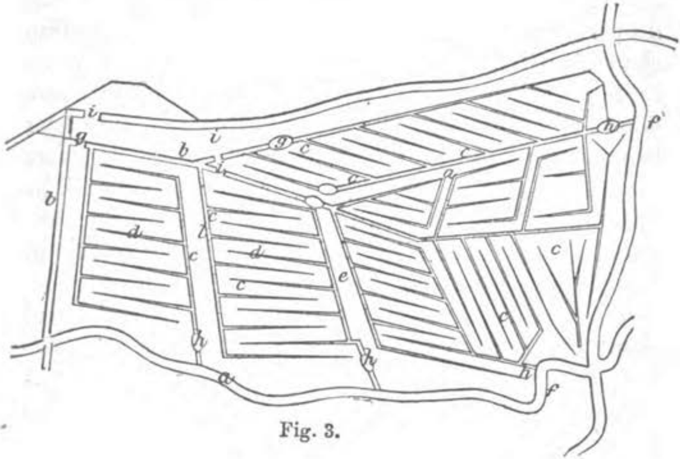


Fig. 3.

the highest part of the meadow, the next object is, to make the conductor large enough to receive all the water that the stream contains if there is land enough to use it. If there is a great fall from the wear or dam (sluice) to where the meadow is to begin, it

Fig. 4.

(the conductor) may be made comparatively deep and narrow (Fig. 4); but on nearly level ground it must be made shallower and wider (Fig. 5), as it is only near

Fig. 5.

the top of the stream that the water has any draught. It is of no use to make the bottom of the conductor deeper than the feeder will draw the water out of it; neither is it of any use to make the bottom of the feeder any deeper than the last floating gutter (or irrigating channel) will draw it off. . . . . In forming the master-feeder it will be necessary to ascertain the breadth and depth that will hold all the water that the conductor brings to it, and thence to the end of the feeder, where the last floating gutter goes out. Its breadth should be diminished all the way; and whatever its breadth may be at the beginning, it should end about 2 feet in breadth where the last floating gutter goes off.

"If the ridges or beds be 10 or 12 yards wide, and about 100 yards long, with 6 or 8 inches of fall, the breadth of the floating gutters should be about 18 inches at the head, or 2 feet, according to the length of the gutter, and about 6 inches at the lower end of the ridge. This diminution of the gutter serves to force the water out over the sides of the beds; and as a part of the water is always going out of the gutter, it is always growing less, and consequently does not require so much room to hold it. The stuff that is taken out of the feeder should be laid smoothly along its sides, with a slope outwardly, and raised about 6 inches above the surface of the ground; and in crossing ridges the hollows must be filled up with superfluous stuff from the high places or out of the drains, so that the top of the banks of the feeder may represent a straight horizontal line, and keep the water above the surface of the ground, which is necessary to make it flow down and over the sides of the floating gutters with proper effect.

"In making the floating gutters, after both sides of one are cut with a spade, by a line, then cut again with a spade down the inside of your lines on both sides, beginning at the head about 5 or 6 inches from your line, so diminishing all the way down to the end, and pointing the edge of your spade so as to make it intersect your outside cut. When both sides are done, the land in the breadth of the gutter will be divided into three strips, the outside of which will be loose, and will turn out whole in triangular furrows, which form the sides of the gutters and keep up the water above the surface of the ground. After the sides are cut, there will remain a fast strip in the middle, which must be taken out and laid in equal portions on the outsides of the said furrows, or into the lowest places. In taking out the fast strip, it is best to leave here and there a piece unremoved, which serves for stops and saves putting in afterwards. These stops will be wanted more or fewer in number, according as there is much or little descent in the floating gutters. When there is nothing left in for stops as above, the defect must be supplied by putting in boards or sods to check and raise the water to the height you want it. Without stops the water would all flow to the lowest end of your work, and there run out too deep; while the higher parts of the meadow would remain dry. Notches are commonly used at first in letting out the water from the feeders and gutters over the beds; but when the sides become older and firmer, it may be made to flow over them. The breadth of the beds should not exceed 10 or 12 yards; but if less than 8 yards, it is best, in general, to put two into one, either with the spade or the plough. The length of a division of floating gutters should never exceed 100 yards in the ridges or beds; because, if they are too long, it makes the water more difficult to regulate, and, if the stream be fluctuating when the water falls in, the upper parts of the beds will be dry. All floating is the better of a descent, from the crown of the ridge to the furrow, of from 1 inch in a yard to 2 inches. This must be attended to if the land is to be formed into beds with the spade or the plough; but where it is in proper ridges before, they may be taken as they are, be the descent less or greater than as above.

"At the lower end of the meadow, and indeed at the end of every set of beds, there must be a main drain, and betwixt every two gutters there must be a small drain, to receive the water that flows over the beds and carry it into the main drain. These small drains must be parallel with and reverse in their dimensions to the floating gutters, least at the upper and largest at the lowest end; whereas the gutters are largest at the upper end and smallest at the lower. These small drains, if in a dry soil, will do 6 inches wide at the head and 18 inches at their junction with the main drain. The stuff that is taken out of them is always wanted to make up hollows, or to make up the banks of the feeders, to carry them through low places to higher ground; but wherever it is put it must be properly smoothed to let the water flow regularly over it.

"When a meadow is large and the surface not all upon one section, but has high and low places in it, more feeders must be made, and more cross or master drains. Sometimes it happens that a feeder must cross a drain in carrying the water from one eminence to another through a hollow: in this case a trunk must be made with boards of the size of your drain and placed in it, and the feeder carried over it. The trunk must be as much longer than the width of the feeder as will be sufficient to give room for proper banks to the feeder, otherwise the weight of the water will force them out. If the feeder be small and the drain large, it will be cheaper to make the trunk or spout correspond with the size of the feeder, and carry the water over the drain in it. Hatches or sluices (one or more according to the size of the feeders) are always necessary in the mouths of them, for excluding or admitting the water at pleasure, and also for changing it when the meadow is divided into divisions."

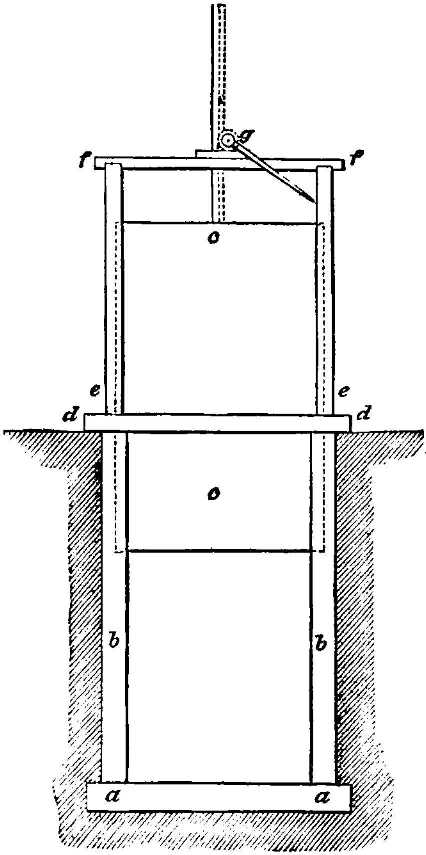


Fig. 6.

Various kinds of sluices are employed to take in water from the river or canal, &c., to the main feeder. Fig. 6 represents a good construction by Mr. R. Scott Burn. "*a a* is the stone sill, *b b* the side quoins in which the grooves are cut, and in which the wood or sheet-iron sluice-door (*c*) slides up and down. The stone flat (*d d*) supports the wooden uprights (*e e*), carrying the cross-bar (*f f*) in which the pedestal of the toothed wheel (*g*) is fixed, this gearing with the rack of the stem of sluice door."

Wooden "stops" for the small channels are seldom used, a turf or a spadeful of earth serving the purpose. Fig. 7, however, illustrates a wooden stop made of "two boards (*a a*) joined together, but kept separate by pieces at the end into which the sluice board (*f f*) is passed, being lifted up by the hand-hole (*g*), and kept apart at any point by the wedge (*h*). The aperture to allow the water to flow through is *b c d e*, the edge (*c e*) being on a level with the bottom of the channel."

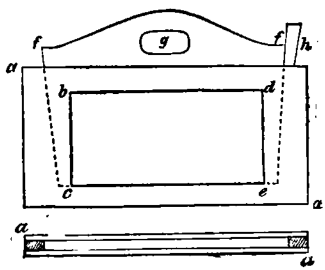


Fig. 7.

Catch-work Irrigation.—This differs materially from the bed-work system. It can be applied to sloping and undulating surfaces as easily as to level lands, and to lands under tillage as well as under grass; it sacrifices no land and costs very little, and it is quite as effective as the more expensive bed-work.

The feeder or conductor, formed as before, is led along the highest side of the field, and a spring or small stream directed into it is made to overflow the side by the end of the ditch being dammed up; but as the water would soon cease to flow equally for any great length, and would wash the soil away in places, small parallel gutters or trenches are cut, at distances of 20 or 30 feet, to catch the water again (Fig. 8); and each of these being likewise stopped at the end, lets the water over its side, and distributes it until it is caught by the next; and so on over all the intermediate beds to the main drain at the bottom of the meadow. Fig. 9 represents a section of this system. The cross gutters must be laid out perfectly level, and of course on most lands will be winding; and these again are sometimes crossed by feeders running from the conductor to the lowest side of the field, thus forming a kind of check work.

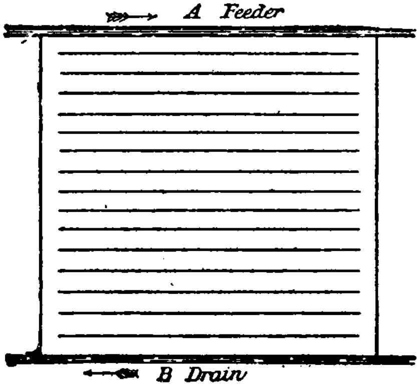


Fig. 8.

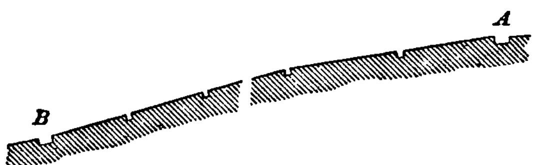


Fig. 9.

Fig. 10 shows the latter plan of catch-work, in which "the channel of supply at *a a* delivers the water to the gutters (*c c*), which again deliver it to the branch gutters (*c*). The water flowing from these over the surface of the land reaches the lowest level, where the catch-drains (*b b*) are placed; these deliver the water to the channel (*b b*) which carries it finally off."

The cross gutters are rapidly thrown out by the plough, and may be renewed every year if necessary on grass as well as on ploughed land; while the principal

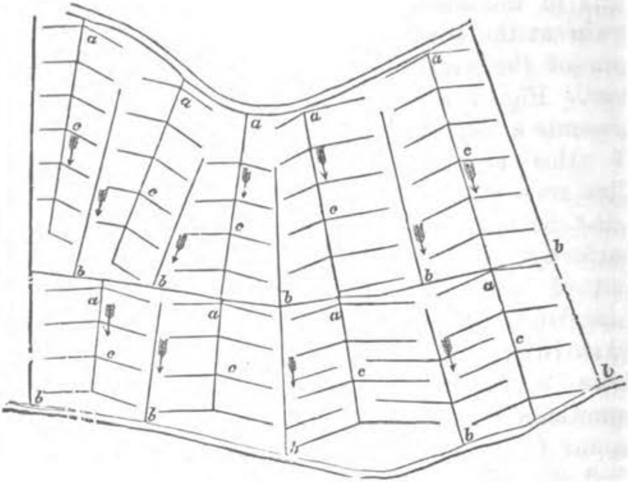


Fig. 10.

feeders and drains remain, and at most only require to be repaired and filled with water.

As to other modes of watering in catch-work, the diagonal system is perhaps the most effective.

In all cases when the water seems to have sunk, it should be taken up again by opening a new trench for it, in order to collect or *catch* it, for diffusing it over another surface.

In Pennsylvania, Dr. Edwards tells us, "hills so steep as not to be arable are watered, and produce greater quantities of grass than flat grounds, without ever having had a forkful of manure put upon them, and are now richer than they were thirty years ago, after having had two crops of hay, and sometimes three, annually taken from them."

He describes the American plan of watering uplands as follows: "The first object, certainly, is to secure a complete command of the spring or stream to be made use of. For that purpose a drain must be made as near the source as the circumstances of the case may require, and the water must be then brought on the same level, by a canal or ditch all along the side of the hill.

"The spirit-level is made use of for the purpose of finding out the proper line to conduct the water. When the true level is found and the canal made, the water should be turned into it, which, if stopped either at the far end or any part of it, with a gate being shut down, it will flow over and irrigate the land below; or the canal may be made so high on the bank that the lower side of it shall be about 6 inches above the water when standing on a level with its source; and it is then let out by small gutters, about 10 or 15 feet from each other, which are spread a little below by arms each way, so as to meet one another in such a manner as to throw all the ground under water. By this mode, if there be plenty of water, the whole ground may be irrigated; but if it be scanty, half of these gutters may be stopped by small sods one day, or two days if necessary, and the other half afterwards, when the first are taken up; so that the whole can be flooded alternately every other day; a practice preferred by some, even where the water is abundant.

"At a distance of near two rods below the first canal another is made, to receive all the water that has flowed over the ground between the two, and again turned out as above;" repeating the process till the lowest level of the field is reached.

"The whole surface of the land to be irrigated should be made so fair and smooth that where the water is turned out to produce its great effect, there should not, to have it complete, be a hollow or hillock, in which a drop of water can stand, or over which it cannot flow."

Sub-Irrigation.—This consists in saturating a soil with water from below instead of from the surface, and is effected by a system of subsoil pipes, which, proceeding from a main conduit or other supply, can be charged with water at pleasure. In some parts of the United States perforated pipes are used for the purpose, but the common drain-pipe answers quite as well. The usual plan is to surround the field with an open drain or main, and intersect it by covered drains communicating with this main. If the field is level, nothing more is necessary than to fill the main, and keep it full till the ground is sufficiently soaked. The water escapes through the joints of the pipes, and rises into the superincumbent soil, by pressure and by capillary attraction, to as great a height as the water is standing in the main drain. In this manner water may be given to the roots of plants in dry weather; and when the saturation is complete the whole of the water may be removed at will by opening the drain outlets and re-establishing free drainage. When the land slopes, the lower ends of the drains must be closely stopped, and the water admitted only into the main on the upper side; this main being kept full till the land is soaked, after which the mouths of the lower drains are opened to carry off the superfluous water.

It is claimed that this method produces all the good effects of surface irrigation with a much less quantity of water, while the surface soil does not bake. For lands under tillage the plan is an excellent one, particularly on porous soils. Of course, by this method, no deposit from the water is left on the surface of the land. It is chiefly adopted on fens and drained morasses, which are apt to become parched in summer; but it would be very valuable for all light soils under green crop in seasons of drought.

Side-Irrigation with Open Drains.—On this system the field is intersected by open drains, at the usual distances, which communicate with the open ditches or drainage canals. When the land is to be irrigated, water is let into the ditches, and thence to the small drains, till it rises to or near the level of the surface;

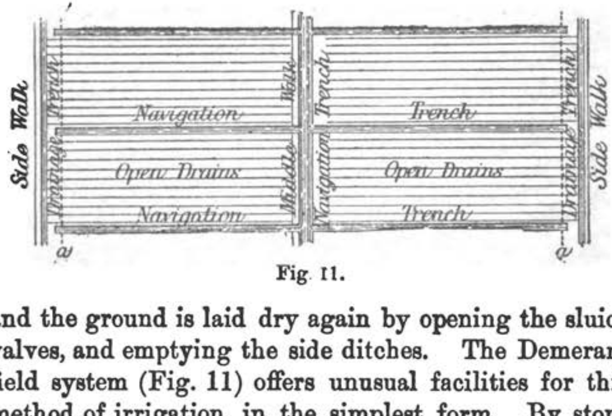


Fig. 11.

and the ground is laid dry again by opening the sluice valves, and emptying the side ditches. The Demerara field system (Fig. 11) offers unusual facilities for this method of irrigation, in the simplest form. By stopping up the small drains at *a a* near their junction with the side-line draining trench, and then filling the navigation trenches to overflowing with fresh water, the open drains become collectors, and the water can be made to rise in them to any desirable height, swamping the entire ground surface if necessary. When the watering is complete, the pressure of water from the navigation trenches is withdrawn, the stoppages in the drain mouths are removed, and the surplus water is free to escape to the draining trench. Where a sandy or gravelly soil rests on a retentive subsoil, this mode of watering may take place without drains by filling to the brim and keeping full for several days surrounding trenches; but the beds or fields between the trenches must not be too great.

Irrigating by Pipes and Hose.—"There are many cases in which the methods of surface irrigation pre-

Fig. 12.

viously described are unsuitable. Where the surfaces are irregular, where the crops are changed several times in a season, where the ground is under biennial or perennial crops, and furrows cannot be maintained, or where the ground is too valuable to be occupied by furrows or water channels; these and other conditions will be favourable to one or other of the following plans. The first to be treated of is that of underground pipes and stationary hydrants, from which water may be distributed under pressure through india-rubber hose and sprinklers (Fig. 12). An elevated reservoir is provided, from which an iron pipe, having a capacity equal to an inch and a half in area for each acre to be irrigated, is carried along the centre of the garden. A 2-inch pipe will be required for two acres, a 3-inch one for four acres, and a 4-inch one for eight acres. From this pipe others are carried at right angles 200 feet apart to within 100 feet of the boundary upon each side. The pipes are laid a foot beneath the surface, or so far that they can never be disturbed by the plough. Upon the lateral pipes, which should be at least an inch and a half in diameter, so that the flow shall not be unduly interrupted by friction, upright pipes, or hydrants, are attached, which project at least three inches above the surface of the ground. These are about 200 feet apart. They are furnished with valves, which operate by means of a square head and a key. Each one is fitted with a cap which screws on or off, and which is attached to the hydrant by a short chain for its preservation. When this cap is unscrewed, a section joint affixed to the end of the hose may be screwed in its place."

"When this apparatus is in operation, the water descending from the elevated tank or reservoir passes through the pipes and the hose, and escapes with some degree of force, depending upon the height of the head, through a flattened nozzle, which scatters it in a thin sheet or broken shower. With this apparatus one man may water copiously five acres of ground in a day or night. Each hydrant being the centre of a plot 200 feet square, serves to irrigate, with 100 feet of hose, very nearly or perhaps one acre of ground. To irrigate five acres in ten hours would give an hour and a half to each plot, and amply sufficient for an active man to get around a plot of 200 by 200 feet."*

An improved nozzle for shower irrigation is manu-

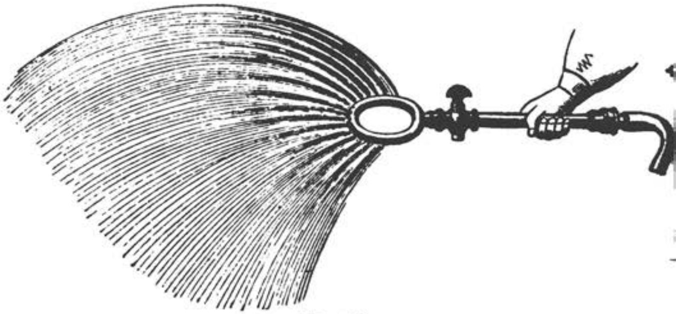


Fig. 13.

factured by Messrs. J. Warner & Sons, London, and is represented in Fig. 13.

Irrigation by Surface Pipes.—By this method the distributing pipes are laid upon the surface of the

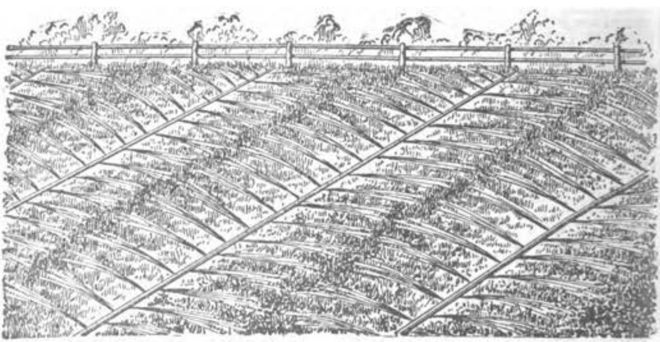


Fig. 14.

ground, and are perforated in such a manner that the water is discharged in a shower of spray upon the

* Stewart's "Irrigation for the Farm, Garden, and Orchard."

ground (Fig. 14). The distance the pipes are laid apart may be 24 feet or more, but this will depend upon the pressure and force with which the water is discharged. The disadvantage of this system is its first cost; but once the apparatus is provided it can be put in operation with little expense, all that is required being the turning on and off of the water at intervals.

Water-Drills, Water-Carts, Garden-Engines, and Syringes.—The water-drill is now in great request for sowing turnip and mangel seeds in dry weather. As these crops are put in at one of the driest periods of the year, its use insures a rapid and healthy braird of the young plants. The drill is a common turnip and manure drill, with the manure-barrel fitted for carrying water and for distributing it in the rows immediately underneath the seed. The quantity of water can be regulated, and either pure water or manure water may be used. In the latter case superphosphate, or guano, is dissolved in water, and the mixture used at the ordinary rate for dry manure per acre. The water-cart is sometimes used in dry weather for watering drilled crops after they are started into growth. Two forms of improved water-carts are shown in Figs. 15 and 16. The former is manufactured by Messrs. Colman & Morton, Chelmsford; the latter by Messrs. James & Son, Cheltenham. Each of these carts is fitted with a short hose for dropping into the

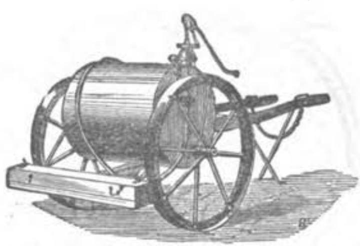


Fig. 15.

tank or well, &c., and a pump for filling it with ease and rapidity. Garden-engines and Syringes, though very serviceable in their place, are of course only useful where a few plants or beds of ground are to be dealt with. Fig. 17 shows a special syringe, manufactured

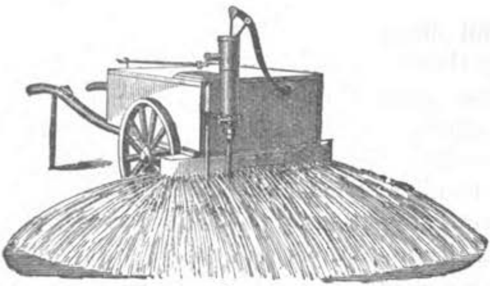


Fig. 16.

by J. Warner & Sons, for washing hop vines. By means of this instrument all parts of the vine are easily

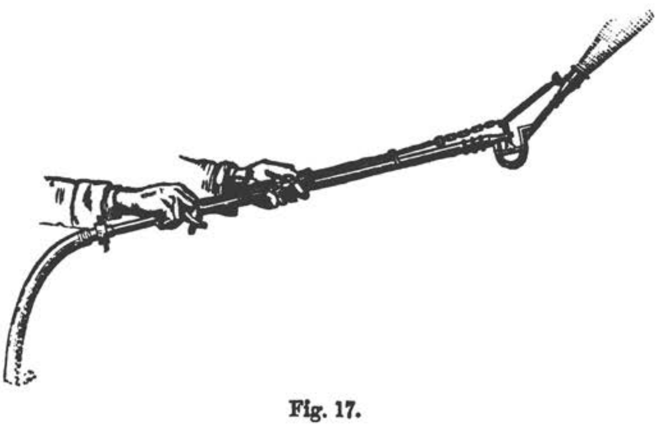


Fig. 17.

reached, and it effects great saving in the washing mixture.

CHAPTER VI.

MANAGEMENT OF IRRIGATED GRASS LANDS.

Application of Water.—On English water-meadows, as a rule, the irrigating season begins at the end of October, and is continued till about the first week in April. The usual plan is to keep the land flooded to a depth of about 2 inches during the months of November, December, and January, for a fortnight or three weeks at a time, and then let the water drain off from it for a week or so before flooding again. In February and March the waterings are gradually shortened to eight days at a time. At the beginning of April the land is left dry, and in May the grass crop is cut.

In November the water is used very plentifully for the first three weeks, after which it is taken off for a week, or changed to another part of the meadow. When the grass turns dark the water should be taken off. A standard work on farming directs that it should be taken off on occurrence of frost. The true rule, however, is not to take it off nor to lay it on in a frost;—not to take it off, because the water, freezing on the ground, forms a coat of ice which protects the grass; not to lay it on, because the ground, being already frozen, can be no longer protected.

In December and January the chief care consists in keeping the land sheltered by water from the severity of frosty nights. In very frosty weather it is better to take off the water from the meadows altogether if it is severe, and likely to continue long; but this must be done at the beginning of the frost; if this has not been done the water should be allowed to remain on during the continuance of the frost. The danger from frost is, that if ice forms under and around the roots of the grasses the plants may be thrown out by the expansion of the water. This can only be prevented by keeping the grass protected by water, or else making the land so thoroughly dry that no injury will result from frosty weather. In spring the young and tender shoots of grass are easily nipped and destroyed by frost, if these precautions are neglected.

In February the management is much the same as in January, only, if the weather is mild, the water will require to be taken off or changed more frequently. If the water remains on for many days about the end of this month, in bright weather, a white scum arises, very destructive to the grass; and if the land is exposed, without water, to severe frosty nights, the greater part of the grass will be killed. The only way to avoid this is to take the water off early in the morning, and turn it over at night; or, if the day be very dry, keep the water off altogether during the frost, for it is only when the grass is wet that the frost has a pernicious effect.

In March, as vegetation sets in, care must be taken to shelter the young grass as much as possible. When the water is changed or removed, a mild day must be chosen for it; and it is best to do it in the morning, that the ground may dry before night, and be able to withstand a frost the better. In this month scum on the water must be guarded against; but, instead of changing the water at stated times, it should be done according to the weather, always taking advantage of a fine day, which may vary the time from a week to once in a few days, less or more.

If the meadows are to be spring-fed, the watering ceases about the middle of March, or the first week in April at latest. Early in May, when the spring-feed is eaten off, the water is used for a few days before laying up the meadows for mowing; and again when the hay crop is carried off.

The watering of grass lands, other than water-meadows, is very simple, as it is seldom practicable to lay them under water, and they can only be irrigated by flowing the water over them. This is done at intervals, which will be determined by the weather more than anything else. As the grass is never completely covered, the irrigation cannot be carried on in frosty weather; so that on high lands, and, indeed, on most catch-work meadows, where the ground slopes or is undulating, it is impracticable to irrigate during winter, and watering has to be delayed until the spring frosts are over. This puts off the spring watering until April or May; after which, however, there is still time to grow a crop of hay. Any attempt to irrigate upland meadows in winter, and to pasture them in early spring, would but injure the meadow by means of frost, and at the same time rot the sheep.

Spring-Feeding.—The great value of water-meadows consists in the early spring feed which they afford, between "hay and grass," by which the farmer is enabled to breed early lambs. As soon as the lambs are able to travel with the ewes, about the middle of March or the beginning of April, the flock is put into the water-meadows. Care is taken to make them as dry as possible for some days before the sheep begin to feed them, and, on account of the quickness of the grass, it is not usual to allow the ewes and lambs to go into them with empty stomachs, nor before the morning dew is gone. The general hours of feeding are from ten or eleven in the morning till four or five in the afternoon, when the sheep are taken off and folded on swedes or mangel for the night, or else put into a dry meadow or pasture where a few swedes or mangel and some box-feeding can be supplied to them. The grass on the water-meadows is daily hurdled out in portions, according to the number of sheep, to prevent their trampling it down; but a few spaces are left in the hurdles for the lambs to get through and feed forward in the rich grass. One acre of good grass will be sufficient to last five hundred couples a day. The great object is to make the water-grass last till the winter rye, barley, and forward vetches, &c., come in for feed; the meadow is then laid up for hay.

Late spring pasturing on meadows is objectionable, as it always lessens the hay crop, and the harm done is usually in proportion to the dryness of the meadow. Water-meadows may be fed during April, and then be laid up for hay; but dry meadows should not be spring-fed at all.

Laying-up Meadows.—In regard to the time of laying-up the meadows, quaint old Tusser says:—

> "Spare meadow at Gregory, marshes at Paske,
> For feare of drie summer, no longer time aske;
> Then hedge them and ditch them, bestowe thereon pence,
> Corn, meadow, and pasture aske always good sense."

St. Gregory is the 12th of March; Paske is Easter; and Tusser's meaning evidently is that marsh meadows may be grazed a month longer in spring than dry meadows, and still yield a good crop of hay, however dry the summer.

After spring-feeding, before any water is given, the meadows should be put into the best condition for laying up. The ditches and furrows should be examined and repaired, the drains cleared, and all rubbish taken off the surface. Any inequalities of the surface should also be remedied with the spade, first taking off the turf, and then replacing it and beating it firmly down. The meadows are next bush and chain harrowed; any rubbish brought up is picked off, and then the ground is rolled with a heavy roller. If any grass seeds are to be sown, it may be done previous to harrowing. Farmyard manure, if given at all, should be applied when the hay crop comes off, and only in a well-rotted state. Artificial fertilizers will rarely be necessary; but if given at all it may be in the form of a top-dressing, after laying-up for mowing.

Cutting.—From the great succulency of the plants produced in water-meadows, the converting of them into hay requires particular attention. It is desirable that the grass should be ready to cut early in the season, not later than the end of June or the beginning of July, when the weather is likely to be favourable for hay-making; and to this end the meadows should be laid up early. It is not advisable, however, to cut the grass of water-meadows too soon, or before it approaches ripeness, as there is then more loss of weight and substance in the making. The best time to mow is when the bulk of the grasses are in flower, unless in cases where the grass has fallen down, and would spoil if it remained uncut. Attention, however, must be paid to the state of those plants which constitute the bulk of the crop, and if the rough-stalked meadow-grass, the scented vernal grass, the soft meadow-grass, are the most abundant, the grass may be cut earlier. In taking off the grass, carts and waggons should be used very carefully upon the meadows, lest ruts may be cut to the injury of the surface. Roadways across the meadows, from point to point, should be previously laid out, using wooden culverts where the roads cross the irrigating ditches or drains.

Repairs.—In addition to what is done at the time of laying-up for mowing, a water-meadow will require some annual repairs in autumn. Thus, in the month of October, when the after-math is fed off, the banks of the feeders must be repaired where they have been trodden down by the sheep or cattle, and the sand or mud that lodges in any of them thrown out. The sides of the feeders and gutters may be trimmed with a large sharp reaping-hook, and the bottoms may get a light shovelling out. The clearings may be trodden down smoothly at the back of the gutters, or put into hollow places, &c.; but it must always be observed not to clean the floating gutters so hard at the lower end as at the upper, that the diminishing proportion of their size may not be destroyed.

Water-Meadow Grasses.—These plants, Dr. Singer observes, ought to be perennial, as it can never be intended that the meadow should soon be broken up. In America, timothy, or meadow cat's-tail (*Phleum pratense*), is greatly in favour for water-meadows; and it is remarked that white clover bears drowning better than any other plant of that nature, although it does not yield the bulk which is desirable in a hay crop. By careful management, re-seeding, and manuring, timothy and clover may be retained in a water-meadow; but many of the following plants are but slightly inferior to them, and, as they grow more abundantly and constantly, are better adapted to this culture:—(1) perennial red clover, or cow-grass, which naturally prospers where the soil contains a due proportion of marl or lime; (2) soft meadow-grass (*Holcus lanatus*), which thrives well in any soft soil, especially if it be also watered; (3) rough-stalked meadow-grass (*Poa trivialis*), which delights in a soil between loam and bog, possessed likewise of a degree of moisture; (4) crested dog's-tail (*Cynosurus cristatus*), which thrives well in watered loams; (5) sweet-scented vernal grass (*Anthoxanthum odoratum*), which hardly fails in any water-meadow where it has been once established, and whilst it adds to the bulk and weight of hay, it likewise communicates, if made in dry weather, the sweetest odour to the whole crop; (6) bent grasses, in particular white-bent (*Agrostis alba*), and creeping-bent (*Agrostis stolonifera*), or the famous *fiorin*, which some recommend in preference to every other, for water-meadows, long and fully irrigated.

The nature of the herbage upon an irrigated meadow, remarks Mr. Stewart, depends greatly upon the skill with which the irrigation is managed. If water is used in excess, the more valuable grasses disappear and inferior ones take their place—such as couch grass, the spear grasses, and other coarse species.

Italian rye-grass (*Lolium Italicum*) is extensively grown under irrigation in England and elsewhere, and yields repeated heavy cuttings of forage for soiling. It is the chief grass grown upon the Italian water-meadows, upon which it yields an aggregate cutting of forty tons and upwards of green fodder per acre yearly.

CHAPTER VII.

MANAGEMENT OF IRRIGATED ARABLE LANDS.

THE irrigating furrows upon cultivated land can seldom be permanent, except in vineyards and the like, where there is not a constant change of crop going on. In such grounds a system of irrigation may be laid out as complete as in the case of a water-meadow, as the work will be permanent in character, and the first outlay will be the last, if the work is properly done. Generally, however, the irrigating channels on arable land will be destroyed at every ploughing, and must be re-made for every crop.

The watering of arable land and crops, though uncommon with us, is universal in warm countries, and even in Southern France, Spain, and Italy. In many cases the crop is grown in drills, and the water is simply introduced in the furrow between each row. In this mode of irrigation, no collecting drains are required, as the whole of the water laid on is absorbed by the soil. The principal expense of the operation is that of preparing the lands by throwing the surface into a proper level or levels. The main conductor carries the water to the higher part of the field, and the rest is easy. A side conductor should be formed along the entire length of the field; so that the field can be watered in sections if wished, by closing the supply-channel at any desired point.

With crops under flat culture, such as wheat or barley, there are other plans available. If the ground slopes, the ordinary catch-work system may be adopted, drawing with the plough light furrows from the main conductor at the top of the field, parallel and horizontal to it, or in diagonal or diamond form, or otherwise, according to the contour of the surface. On level ground the land may be ploughed into beds, and the water introduced in furrows during the growth of the crop: this may be done either by a system of side-irrigation, the soil absorbing the water from the ditches, or by regular flooding.

"In the flat plains of the Rioja," Mr. Roberts * tells us, "a small mound or embankment of clay is formed around each field; and when irrigation is required, the water is admitted from some of the minor channels, of which there is a network on every farm, through an opening in the bank, usually placed at the corner of the field. It is then allowed to flow until the enclosure is completely covered to a depth of about three inches, when the inlet is closed with a sod, and in a few minutes the water is all absorbed by the parched soil.

"In sloping ground the Spanish farmers often level the field into a series of horizontal plots or terraces, that each inclosure may be irrigated in the manner above described. When this is not done, water is admitted at the high side of the field, and allowed to flow over it; and numerous little cuts, like plough tracks, with their corresponding mounds, are made across the enclosure, or at right angles to the direction in which the water flows, so as to check its velocity, and thus facilitate its absorption by the soil."

This system is illustrated in Figs. 18 and 19. The

* "Irrigation in Spain."

" divisions do not slope on both sides, but incline in one direction, as shown in Fig. 18, at *a b*, *a b*, *a b* ; but are horizontal, in the direction of the arrows in plan,

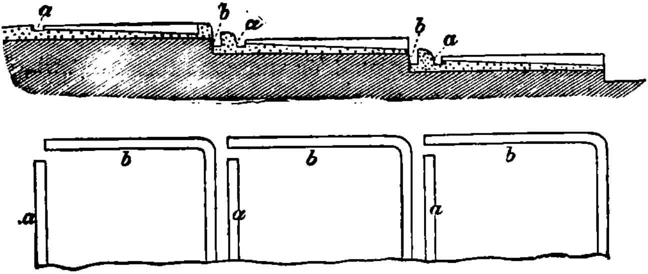


Fig. 18.

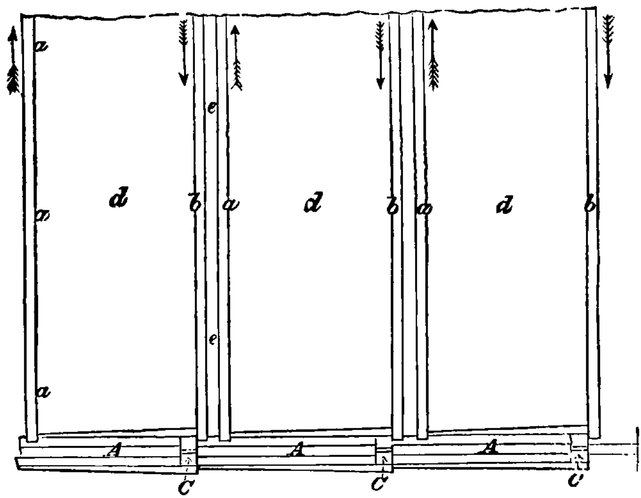


Fig. 19.

Fig. 19. The channel of supply is at *A A*, and sluices are provided at *C C C*, by which the water can be let into or kept out of the channels of distribution (*a a*),

placed at the upper side of the inclined divisions (*d d*). The channels of distribution (*a a*) are divided from each other by small embankments or ridges, as shown in section in Fig. 18. The water, after passing over the surfaces (*d d*) is taken up by the channels (*b b*)."

Mr. Roberts comments on the skilful manner in which the Spanish farmers, when irrigating their lands, conduct the water from one field to another, or from one part to another of the same field on a different level. When all the lower parts are irrigated, they construct temporary dams with the hoe, and by this means raise the level of the water so as to be able to reach the higher parts of the field. A sod or a stone serves the purpose of a hatch, or "stop-off."

Time of Watering.—The evening hours are considered the most favourable time, but this rule is nowhere universally observed.

Application of Water.—Watering should not be deferred until the ground is too dry, as it does not bake so readily afterwards. In dry weather, a moderate watering should be given before sowing or planting, and for a time afterwards the ground should only be kept moist enough to favour germination, and prevent the surface hardening. For the young growing plants, moderate, frequent waterings are best. No rule can be laid down, however, that will be generally applicable. The various field crops which may be brought under irrigation all call for special treatment, and this will vary with the district in which they are grown. The reader may here usefully refer to what has been already said on this point under the heads of crops suited to irrigation, and the number of waterings bestowed on different crops, in Chaps. III. and IV. In the case of nearly every crop, the ground must be allowed to get occasionally dry; for even those crops which require watering most are easily injured if the water is in excess, or is allowed to remain on too long.

Cultivation.—The soil should never be stirred when wet. Tillage and cultural operations "should be timed with reference to the watering, or the watering should be so timed with reference to them, that these operations may be performed when the soil is dry and just before watering."

CHAPTER VIII.

SWAMP IRRIGATION.

Swamp irrigation is practised more or less on the rice or paddy fields of India, Egypt, Southern Europe, and the Carolinas, and other south-eastern states in America. These crops are generally produced on tide-swamps, or other low-lying grounds, which possess no means of natural drainage; and under this system the land is commonly laid under water for weeks at a time, sometimes, indeed, from the time of sowing till the time of reaping.

The rice plant appears to adapt itself in a very wonderful manner to swamp life. Even here, however, there is doubtless no exception to the general rule, that stagnant water is injurious to the higher forms of vegetation. Where the produce of rice under such treatment appears to be as great as is to be expected from the most skilful and intelligent culture of the plant, it will probably on examination by analysis be found to compare but poorly in nutritive value with that grown under different conditions; otherwise, the presumption is that, though the water was retained on the field during the whole time of the growth of the crop, it was not really stagnant, but constantly undergoing renovation, by percolation or some other means.

Rice irrigation has been well described by the late

Robert Russell, of Kilwhiss, who visited the Carolina rice plantations in 1865, and published an interesting account of them in the *Transactions of the Highland and Agricultural Society* for 1866.

"It is on the tide-swamps of the Savannah, and the numerous other rivers in Georgia and the Carolinas," says Mr. Russell, "that the fine rice known in Europe as the Carolina rice is cultivated. The production of rice for exportation is in a large measure confined to these swamps; and it is further limited to the *fresh* tide water swamps, for where the tides are salt, or even brackish, they are unfit for irrigation.

"Though a considerable quantity of *upland rice* is raised here and there for domestic use, none of it is reckoned sufficiently good in quality for exportation. The rice which grows in the tide-swamps is of much better quality than what grows in dry cultivation. The pickles of the irrigated rice are large and equal in size, and the husk is easily separated from the kernel; whereas the upland rice, being smaller and more unequal, the sample is not only inferior, but there is a great deal more waste and labour in its preparation for market."

Another objection to the culture of rice on the dry upland soils is the great amount of manual labour which is required to keep the crop free from weeds. The lengthened period of hot weather over which its growth is extended, and particularly the circumstance of this crop, like our cereals, either being sown broadcast or in narrow drills which do not admit of horse-hoeing, tend to give great encouragement to weeds, so that its culture demands too much hand labour to be generally profitable.

"The swamps which form the rice grounds were reclaimed by erecting embankments along the sides of the river, and preventing the overflow of the tides.

"Main canals, having sluices on their mouths, are dug from the river to the interior about 20 feet in width; and as they sometimes extend across the whole breadth of the swamp, they are more than 3 miles in length. The rice plantations are subdivided into fields of about 20 acres each. The fields have embankments raised around them, with sluices communicating with the main canal, so as they may be laid dry or under water separately, according as it may be required. Numbers of open ditches are also dug over the grounds, for the purpose of allowing the water to be more easily put on or drawn off.

"From the nature of the works which are required to reclaim the tide-swamps, and render them fit for cultivation, large capitals are invested. A great expenditure of labour is constantly required to maintain the banks in good order, to clean out the drains and canals, as well as to keep the sluices and valves in repair. It would be out of place here to give any detailed estimate of the expenses and profits of rice culture. The fact, however, of the rice grounds being higher in value than any land devoted to any other crop in the south-eastern states, is quite sufficient to attest the profitableness of rice culture. Nor is this so much to be wondered at when it is considered that the land which is capable of raising rice with advantage is comparatively limited, and has been almost all occupied for a considerable time."

In Carolina there is considerable diversity in the mode of cultivating the rice crop. "Some planters plough all the grounds every year. Those who follow this system give a light furrow in the beginning of

January, and afterwards make shallow furrows or drills, 15 inches apart, to receive the seed, which is sown broadcast at the rate of from two to three bushels per acre. A small quantity of water is then admitted for a day or two until the seed sprouts.

"The most approved and general mode of cultivating the rice fields, when free from weeds, is to sow the seed without ploughing. The stubble of the previous crop is burned over in spring, which is easily effected from the large quantity which is left at harvest. A negro then goes into the field, and makes a rut with a hoe between the rice rows of the former crop. This serves as a receptacle for the seed. Sometimes this operation is done by a small drill-plough. The seed is either covered by a rake, or the water is admitted at once, and covers it by washing down the soil.

"In all cases, the water is admitted to the fields as soon as the seed is sown, and when the young shoot appears above ground the water is drawn off. In the course of a week the crop usually receives another watering, which lasts from ten to thirty days, according to the progress which vegetation makes. This watering is chiefly useful for killing the land weeds that make their appearance as soon as the ground becomes dry. But, on the other hand, when the field is under water, aquatic weeds in their turn grow up rapidly, and, to check their growth, the field is once more laid dry, and the crop is then twice hand-hoed. By the 1st of July the rice is well advanced, and water is again admitted and allowed to remain on the fields until the crop is ripe. This usually takes place from the 1st to the 10th of September. The water is drawn off the day previous to the commencement of reaping."

In the Piedmont district, in Italy, where a great deal of rice is cultivated, the ground is first put under water, then worked up into mud, before the rice is sown broadcast over it. The water is then turned off, and the rice is left to germinate in the damp earth before being irrigated again. After this it is left almost constantly under water.*

In some of the paddy-growing districts of India the same course of puddling preparatory to sowing is followed. The land is ploughed several times while under water, and in the operation the soil is worked into a puddle, by the ploughs and by the feet of the cattle. It is then left to stagnate for a few days, after which more water is let on, and the ploughing and puddling repeated. Where vegetable manures are applied, these are trodden into the puddled soil. Before seeding the ground, the surface is smoothed by means of a heavy plank drawn by cattle.

"The rice grounds," Mr. Russell concluded, "are comparatively healthy to white men in winter, but the very reverse in summer and autumn when the crops are growing and ripening. It has been often remarked that the swamps, in their original state, along the southern rivers of the United States were by no means so deleterious to the whites as they are now, when brought under cultivation. This seems to apply, to a certain extent, to all the rich alluvial soils in the river bottoms, but is particularly applicable to the rice grounds that are irrigated by the tides. Indeed, the undrained swamps remain comparatively healthy so long as they are covered with the natural vegetation. The mere stirring of the soil, and the exposing of it to the atmospheric influences of a hot climate, invariably

* Moncrieff, "Irrigation in Southern Europe."

give rise to malaria. For this reason, the Campagna in Italy became much more unhealthy, as Dr. Arnold states, in his *Roman History*, after its drainage. There is nothing of course deleterious in the mere culture of rice; it is the mode in which the irrigation is managed. This opinion is confirmed by the fact that the rice grounds at the mouth of the Mississippi, on which the water is not allowed to stagnate, are more healthy to the white inhabitants than either the sugar or cotton grounds of the lower Mississippi that are under dry culture. But the practice adopted on the tide-swamps of Carolina, of laying the fields dry at intervals during summer and autumn, seems to give rise to miasmata of the most deadly character to the white inhabitants, but from which the coloured are exempt. The planters, with their families, invariably leave the rice grounds during the hot season, and remain in a more healthy part of the country until the crops are harvested. And though the negroes are not liable to those diseases which are so fatal to the white inhabitants in summer, yet they do not increase in the rice districts."

The water-cress beds, which are to be found in the neighbourhood of London and all other large cities, afford a more striking example of swamp vegetation than the rice grounds we have been considering. Water-cress is grown on ground entirely under water, but the water is never altogether stagnant. It is a plant that can only be grown where there are running streams, and it also favours a limestone or chalk formation, so that in all but small artificial beds, its cultivation is limited to comparatively few localities.

In some cases it is merely allowed to grow in the natural stream, but those who make a business of growing it, increase the area by making beds at right angles to the stream. The beds are excavated to a depth of about 8 inches, and are usually 5 feet wide, and of a length governed by the level of the land. They should be so constructed that the water from the stream may be directed into them by the use of board dams, and an overflow channel must be provided. Lime or chalk may be added to the bottom of the beds, if the soil is naturally deficient in calcareous matter.

Water-cress is naturalized in many streams, and where it occurs a supply may be secured for stocking the beds. The plant throws off roots at each joint below the surface, and if the stem be made into cuttings, each of these fragments, if set in the soil of the bed, will soon form a vigorous plant. The cuttings may be set a foot apart each way immediately before the water is let into the beds.

Where cuttings cannot be procured, the plants can be readily raised from seeds. If the seeds are sown in a box in good garden soil, and kept very moist, a supply of plants for transplanting will soon be at hand. The starting of beds of water-cress should begin in early spring.

CHAPTER IX.

SEWAGE IRRIGATION AND LIQUID MANURING.

THOUGH there are various ways of utilizing sewage, irrigation is the method which has been most extensively practised, and is the only one which demands notice in this work.

"By sewage irrigation the greatest luxuriance of growth known to English agriculture is obtained. It is adapted to all irrigable crops; but the best results are obtained with rapid-growing succulent plants, such as Lucerne or Italian rye-grass. The sewage is poured on at the rate of 400 tons per acre, equal to a thickness of 4 inches of water, during a few hours, twice in the growth of a single crop or cutting. Drainage, deep cultivation, and subsoiling should accompany the process; these tillage operations being only performed, of course, when the land has been laid-up dry. The drained and deeply-cultivated soil then passes the whole of the rich and fertilizing sewage amongst the fibrous roots of the plants, by which its substance is permeated. By this practice, a cutting of 10 to 20 tons of succulent forage is obtained as the result of not more than a month or five weeks' growth. The land is soaked twice or thrice, at intervals of a fortnight after each cutting; and four or five cuttings are thus obtained from the application of 3,000 to 12,000 tons of sewage in the course of the year. Here, as well as in ordinary irrigation accompanied by land drainage, the result is due to an added temperature, and an addition of plant food, both of which the soil experiences; and especially to the constant motion and passage of this food beside and amongst the hungry roots of the plants which feed upon it." *

Nearly all the sewage farms in this country are laid out on the "catch-water" system, which consists in floating on large quantities of liquid sewage over a number of successive breadths of land. The objections urged against this system are—(1.) That the bulk of the water escapes by flowing off the surface, and not through the soil to the drains; and that, therefore, there is no real security that the sewage is purified at all: the fact that it flows off the surface, showing that there is more liquid applied than the land can absorb. (2.) That as the essence of the catch-water system is the pouring of sewage, and of the same particular volume of sewage, over successive areas of land, all the areas of land cannot be equally fertilized, since the sewage cannot be made to flow evenly over all the land.†

These objections apply with even more force to the "Pane-system," which is analogous to the Spanish system of irrigation by water, where rectangular and generally square plots of land are laid out perfectly flat, surrounded by a low bank, and generally on successive levels. The upper plots, in such cases, must evidently retain the whole of the suspended matter which is contained in the liquid sewage, leaving little else than clear water to flow off to the lower levels.

* "The Soil of the Farm." By John Scott and J. C. Morton.
† W. Hope "On Sewage Irrigation."

The Romford Sewage Farm, in the occupation of Mr. Hope, has been laid out in beds on the ridge-and-furrow system, each bed being 30 feet wide. The ridges are raised up in the centre, with a carriage or gutter along the ridge, over the sides of which the sewage flows, as in some water-meadows. Mr. Hope considers that this system of sewage distribution is the best of all, even for arable lands, and presents no difficulty to horse or steam cultivation; as nothing, in his opinion, is more simple than to form a low ridge, by means either of the horse or of the steam-plough.

On hill-side lands, which do not admit of irrigation by the ridge-and-furrow system, Mr. Hope adopts another plan. The hill-side land is ploughed horizontally with a "turn-wrest" plough, and then with a double-mould-board plough going in the same direction, across the hill, it is thrown into little ridges, as if for potatoes. The sewage is applied to this hill-side from a carrier running along the top, the across-hill furrows effectually preventing the liquid scouring away the earth from the plants. On this system Italian rye-grass, &c., cannot be grown, nor can cereals; but as the slope of the hill-side is far too rapid to permit of the application of any liquid by irrigation, if the surface were left smooth, this is no drawback.

At Edinburgh, where sewage irrigation has been practised with marked success for more than 100 years, about 250 acres of the Craigentinny and Lochend meadows are flooded with crude sewage, at the rate of 2,500,000 gallons every 24 hours. Of this land, 200 acres are in permanent pasture, and 50 acres in Italian rye-grass. The irrigation is carried on in the rudest and cheapest way by the owners of the land adjoining the streams of sewage; no cost having been incurred in providing permanent carriers of any kind. The permanent grass is cut about four times in the season, and yields an aggregate crop of about 40 tons per acre. The Italian rye-grass is cut five times, and yields as much as 60 tons to the acre. The whole produce is sold, by public auction, at the beginning of April in each year, in small allotments, and realises from £20 to £40 per acre. It is eagerly bought up for cow-feeding, by dairymen in and around Edinburgh; who, in addition to the price paid for the plots, cut and remove the grass at their own expense. The annual cost of applying the sewage, and receipts for the produce, are given by Mr. Birch* as follows:—

RECEIPTS.	£	EXPENDITURE.	£
250 acres of grass, at an average of £30 per acre	7,500	Wages of watermen—three in summer and one in winter—and cost of cleaning out carriers .	180
		Estimated rent of land, 250 acres at £2 per acre per annum . . .	500
		Balance . . .	6,822
	£7,500		£7,500

This statement, however, is incomplete. The rent ought to be at least £5 per acre; and nothing is charged for the sewage.

"About 8 acres of the Craigentinny Farm, which is land of excellent natural quality, but too high to be irrigated by gravity, has had sewage pumped on to it by steam power. This land has received about 3,000 tons of sewage per acre in six or eight waterings during the year, and the rye-grass grown upon it has realised from £25 to £36 an acre—prices equal to those obtained at

* "On Sewage Irrigation by Farmers."

Lochend, where four times the quantity of sewage has been applied."

It is estimated that the yield of land under sewage irrigation, with forage and root crops at least, is five-fold greater than the yield of the common agriculture of England. The quality of sewage-grown crops is also higher. Thus the proportion of cream yielded from sewage-fed grass at Croydon is stated to be about 15 per cent., whilst that obtained from ordinary pastures is only about 10 per cent. The increase of saccharine matter in sewage-grown root crops is so great as to give the crops so grown an entirely new value, in addition to the greater weight produced. On one sewage farm, Mr. E. Chadwick, C.B., tells us the rhubarb grown is so superior that it is used for making a champagne, and a wine of the character of a "still hock."

At the Annual Conference on National Water Supply, Sewage and Health, held in 1879, Mr. Colebrook, as chairman of the Reading sewage farm committee, stated the result of their experience the preceding year, particularly in the growth of mangold under irrigation. The highest weight per acre was 110 tons and the lowest 77 tons; which, he believed, was the heaviest weight ever known to have been grown. There was this peculiarity in the growth of the mangold ; it was intended in the spring of the year to irrigate the land while the crop was growing, but the spring was wet and they were not able to hoe the land when they wanted, and when they were able to do so the weeds filled the trenches and they could not get the sewage on to the land while the crop was growing. He pointed out that for this reason he believed it was quite possible to overdose the land with sewage, and the result they obtained was chiefly owing to not having done so. The crop of rye-grass was equally good. They cut six excellent crops during the year of not less than 20 tons per acre each crop, whilst the year before they had seven crops. They had rigidly excluded storm-water, and he attributed a great deal of their success to that.

At Bedford, where the sewage of 20,000 of the population is applied to 180 acres, chiefly of market-garden culture, the weights per acre of the principal crops have been as follows:—

	Tons per acre.
Italian rye-grass, per crop (sometimes cut four or five times a year)	25 to 30
Carrots	24 „ 30
Onions	12 „ 16
Potatoes	12 „ 15

As much as £53 per acre has been realised with a crop of celery, and from £30 to £40 per acre with crops of onions, rhubarb, and asparagus.

In regard to the price which a farmer can afford to pay for liquid sewage, when poured over his land, it has been said that for its use to be profitable the price must not exceed ½d. per ton. At 400 tons per dressing this is equal to 16s. 8d. per acre, and as the land requires in most cases to be dressed six or eight times, that price is clearly prohibitive.

At Cheltenham, where the corporation land under sewage is not sufficient to utilise the whole of the sewage at their disposal, it is applied to neighbouring private lands at a charge of 7s. per acre for each dressing. The corporation lets its sewage-fed land at over £6 an acre, and probably not more than one-third of this rent can be charged to the sewage, as the lands are only dressed on an average about five times a year.

Sewage is best applied to land under tillage, or to grass land that will be mown. If it is not positively dangerous to graze land while under sewage irrigation, it is at any rate objectionable, and should never be practised, unless, indeed, the land has been laid dry for a considerable time. That any ill effects are produced by feeding dairy cows or other stock on sewage-grown crops there is not the least reason to suppose. The soil itself cannot be injured by sewage nor even the crops, unless the dressing of sewage is immoderately large.

"Sewage-sickness," remarks Mr. Birch, "is a term that has become common because it sounds appropriate; but, as a matter of fact, time has no effect in making land sewage sick, for its pores may be filled, as at Edinburgh, year after year, with infinitely more dissolved manure than can be made use of by vegetation, and the land will continue to be as productive and as capable of receiving sewage as ever. A crop may, however, be ruined if it is covered with sewage, even although it may not have had enough for its manurial requirements; or land may be done more harm to than good, temporarily, by one single ill-timed dressing. Experience has proved that over-feeding with sewage has no ill effect, although land may be choked with it in one meal."

Liquid Manuring.—By this term is understood the practice, now seldom adopted except on a very small scale, of applying the drainings from the stables or from the dunghill, direct to the land in the liquid form. The use of liquid manure is no doubt very effective, but it is the extract of the dung-heap, which is afterwards of greatly diminished value. In the majority of cases, therefore, it will be found best to apply the liquid part in conjunction with the dry portion of the farmyard manure.

In order, however, that the liquid manure which flows from the cattle-yards and from the dung-heap may not be lost, it should be collected in tanks. This will be useful whether the practice of liquid manuring is adopted or not, as in the latter case the dry manure may be made to absorb it.

If the dung-heap is made on an impervious bottom, or a small tank or vat is sunk in the ground at the lower end of the pit, the drainage from the manure will flow into it, and, by attaching a small hand-pump to the vat the liquid that there collects can be pumped back again upon the heap, whenever it is deemed desirable to moisten it.

Where liquid manuring is to be practised, the liquid in the tank may be distributed over the lands in various ways and by various means.

On a moderately large scale it will probably answer to lay down pipes above or under ground. Through these the water can be made to flow, by gravitation where practicable, or otherwise by pumping. The hose-and-jet system, which has failed in sewage irrigation from the large quantities of liquid which had then to be dealt with, will answer better here; as, although it will be found more expensive than a system of perforated surface pipes, which are self-working, the hose-and-jet system enables the manure to be directed where it is most wanted. On a smaller scale liquid-manure carts may be used. These will be found not very expensive to begin with, and will do a considerable amount of work. If the land is near by the tank, a man and a boy, with one horse and two carts, will water ten acres a day, at a cost of about a shilling an acre.

Fig. 20 is an illustration of one of Bamford's chain-pumps employed in filling a cart from the liquid-manure tank. For liquid manure and sewage the chain-pump is the best that can be used. It requires a little more power to raise a given quantity of water than a good lift-pump; but it has other advantages. Having no

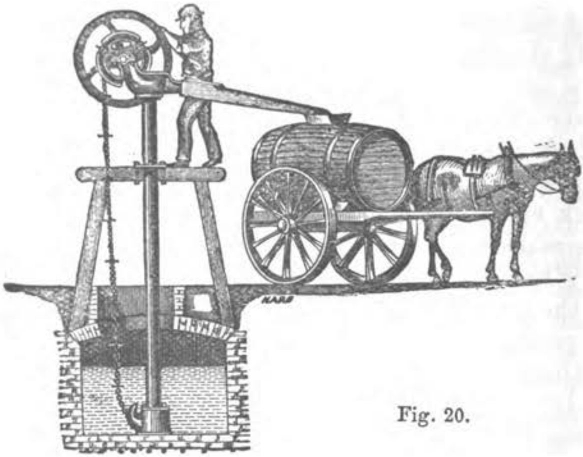


Fig. 20.

valves it is not easily choked; it seldom gets out of order; and as it is empty when out of use, it is not liable to be injured by frost.

Fig. 21.

Fig. 21 represents a distributor, manufactured by Messrs. S. Owen & Sons, London, for attaching to liquid-manure carts, with braces necessary to fix it. It can be removed at pleasure when the cart is required simply for water only.

For gardens, and other small plots of ground, a hand-barrow or garden-engine, with a small force-pump and a distributing hose and jet attached, similar to that shown in Fig. 22, will serve every purpose.

Fig. 22.

Liquid manure may be applied with great effect to all crops. The quantity to be used will depend on whether it is pure drainings from the stalls and the dung-hill, or has been diluted with rain-water. It is seldom desirable, even where possible, to use it the full strength. Diluted with, say, two-thirds water, it may be applied at the rate of 1,000 to 2,000 gallons per acre each dressing, and the dressings may be repeated as frequently as in sewage irrigation.

"Great advantage has attended the use of the water-drill for sowing turnip and mangold seed in dry seasons. By applying the artificial manures in a liquid state, the germination of the seed and the subsequent brairding can generally be relied on. In a dry climate the water-drill is desirable in any year, if root crops which have to be put in at the driest and hottest seasons are to be successfully cultivated. The same quantity of manure is used as in the dry state, and the quantity of water is regulated by the condition of the land and the dryness of the atmosphere. Superphosphate and guano are the most suitable manures for the water-drill."* Soot is also well adapted for applying in the liquid form, either by means of the water-drill or by flowing on through pipes or otherwise.

* "Soil of the Farm."

CHAPTER X.

WARPING OR SILTING.

THIS species of irrigation consists in repeatedly flooding low-lying tidal or river lands, and allowing a succession of sediment to be deposited. Sometimes the object is only to fertilize the land, but more generally it is practised with the double purpose of raising the surface of low and swampy ground.

In either case, warping depends for its effect upon the presence of much suspended alluvial matter in the water used. Being stirred, and kept in motion by the tide, that alluvial matter is, by the process of warping, conveyed over the adjoining lands and there deposited during a period of rest. As soon as this has been done, the clear water is drawn off slowly, so that the new deposit is not disturbed. Another flood is then admitted, and so on until the warp is completed. In this way the thinnest and poorest soils, if favourably situated, may be covered with the richest alluvial to almost any depth.

One tide will leave, on an average, one-eighth of an inch of warp; and in this way $3\frac{1}{2}$ feet of added soil has been obtained in three or four years. Dr. Anderson tells us that in one experiment, where the water used contained 233 grains of mud per gallon, 210 were deposited during the warping.

Warping is effected by a cut or canal from the sea or river, with sluices for the admission and discharge of the water, which is confined to the grounds intended to be warped by surrounding banks raised to the required height. The higher the banks and the deeper the sheet of water that can be impounded the better, as a greater burden of sediment will be deposited; but the height of the bank is, of course, limited by the difference in level between the land surface and the water in the canal.

In these banks there are fewer or more openings to let in and out the water, according to the size of the field to be warped. In general they have only two sluices, one called the flood-gate, to admit, the other called the waste-gate, to let off the water gently. These are enough for 10 or 15 acres. The flood-gates are placed so high as only to let in spring-tides, and the waste-gates are so constructed as to let the water run off between the ebb of one tide and the flow of the next. To avoid the danger of the newly-deposited matter being stirred up and carried off again by the retreating water, the waste-gates may be made to open at the top instead of at the bottom.

Seasons for Warping.—The dry months of summer are considered the best for this work. Land may be warped, however, in any season, provided the water is always muddy; in other cases it should be practised more particularly when the weather is dry and the fresh water in the river very low. When the season is wet, and the river full of fresh water, warping cannot be advantageously executed. The fresh water then mixes with the tide, makes it not half so muddy and thick, and consequently incapable of depositing the same quantity of sediment.

Effects of Warping.—"It is easy to understand the importance of the effects produced by adding to any soil large quantities of fertilizing mud. Herepath has calculated that, in one particular instance, the quantity of phosphoric acid brought by warping upon an acre of land exceeded seven tons. As, moreover, the matters are all in a high state of division, they must exist in a condition peculiarly favourable to the plant. The overflow of the Nile is only an instance of warping on the large scale, with this difference, that it is repeated once only in every year, whereas in this country the operation is repeated at every tide until a deposit of the desired thickness is obtained, after which it is stopped, and the soil brought under ordinary cultivation."*

The fertility of warped lands is so great that they have been known to yield full crops for fifteen or even twenty years in succession without manure. When laid down in grass seed the land is not warped, for the mud would destroy such a crop.

There can be no doubt, however, that the warp of some rivers is much more valuable than that of others. The value must depend on a variety of circumstances, such as the quantity of valuable ingredients contained in the mud, and the proportion of the several ingredients. The presence of any one useful or essential ingredient must add value to the warp, and the greater the proportion of all of them the more valuable will be the deposit.

Mr. Moncrieff † gives an example of this work having been carried on with great success near Avignon, by means of the water of the Crillon canal. M. Thomas, a merchant of that city, having a property composed of

* Anderson's "Agricultural Chemistry."
† "Irrigation in Southern Europe."

gravel and stones, and fit only for grass crops, laid some of it out in terraces, and obtained the use of 14 cubic feet per second of water from the Crillon canal, which he turned over it for the four winter months of every year. After three years he found he had covered an area of 22·2 acres with a coating of the finest alluvial matter, from 20 to 27 inches thick. The cost of the operation, including a water-rent of 16s., was just £7 per acre. The land, which before had been worth £19 8s. 6d. per acre, was valued after this improvement at £113 7s., and yielded seven or eight crops of wheat without requiring any further manure.

Soils and Situations for Warping.—No land but such as is on a level or below that of spring-tide, or similarly placed for river or canal flooding, can be improved by this process. Of lands so situated there are, however, extensive areas along the shores of the British Empire. In almost every Firth in the three kingdoms, and all along our shores, may be seen extensive tracts of barren sands and mosses which are overflown by spring-tides; and however barren they are, they may be reclaimed and rendered fertile by warping. Cherrycob sands were reclaimed by this means, and are said to be 4 yards thick of warp.

"Some of the marine mosses are so loose and pulpy in the subsoil that if drained they would be reduced to a level sufficiently low for warping, especially if the coarse and useless herbage on the surface were in the first instance pared and burned. If afterwards warped in the manner above described, they would become the most fertile soils in the empire. Besides, it is often more easy to rebank this than any other soil; for if a river or broad ridge, 30 or 40 feet wide along the bank of the river, were left undug and planted with willows, it would serve as an impervious bank to shut out or let in the water at pleasure. While the rest of the surface was dug, and drained, and cropped, and thereby reduced to a low level, this bank, left undug, would not sink in the same proportion, but might serve the purpose at least of an excellent foundation for a more solid bank, even though of itself it might be too light, loose, or low to serve that purpose."*

Cost.—The expense of warping has been variously stated at from 30s. to £10 an acre. In ordinary circumstances it can seldom cost more than the smaller sum, as after the banks and sluices are fixed, which outlay cannot be wholly charged on the warping, the only expense will be the occasional wages of a man to attend the sluices. On the other hand, poor land has been so raised in value by this outlay as in many cases to repay the cost in a single year.

* "General Report of Scotland."

CHAPTER XI.

COST OF IRRIGATING LAND.

THE cost per acre of irrigating land will, of course, depend on a variety of circumstances. It will vary according to the mode of irrigation adopted, the nature of the work, the configuration of the land, and the natural roughness or smoothness of the surface, the distance from the source of water-supply, and the means by which the required amount of water can be obtained.

Bed-work irrigation is the most expensive; but even here the cost will vary considerably. If the ground is smooth on its surface, or in regular ridges; if the water can be easily brought to the meadow, and neither wear nor conductor is necessary, the cost may not exceed £3 per acre. If, however, the land has a rough and irregular surface; if a long conductor, and a proper wear be required, with hatches both in it and in the feeders, the cost may be £10 per acre.

"Few people unacquainted with the art of irrigation," says Mr. Stephens, "and the regularity of form which the adjustment of water requires, have any idea of the expense of modelling the surface of a field. Where the ground is nearly level, and the surface covered with turf, the turf may be taken up, the ground properly shaped, and the turf replaced for £3 per acre; as was instanced in one case belonging to the late Sir Charles Menteath, of Closeburn, in 1826; whereas, in a case of Mr. Lawson, of Cairnmuir, in Peeblesshire, the cost was £12 per acre. In one field it cost Mr. Simpson, of Glenythan, Aberdeenshire, about £7, and in another field only £1 16s. 9d. per acre. From £7 to £9 may be taken as a fair average of the expense of converting land into water-meadow. Unless, therefore, the advantage to be derived were considerable, such an expense would not be justifiable; but in all cases where meadows have been well managed the yield has at least doubled."

The expense of forming some of the Wiltshire water-meadows has much exceeded £10 or £12 per acre. £20 and even £40 per acre, have, it is said, been expended in the formation of some of these meadows; but the latter sum seems altogether unreasonable, even for the most elaborate work; though no doubt the value of these meadows, which are worth an annual rent of from £5 to £10 per acre, will warrant a large expenditure, so long as it is judiciously made.

Where a new meadow is to be formed on the bed-work plan, and the ground is favourable, the whole of the work within the boundary fence may be done by the plough, except a little final touching-up and shaping out of the channels and gutters, which would have to be done by the spade, and need not cost more than £2 to £2 10s. per acre. The width of the beds or ridges is first set out, then the land is ploughed two or three times, always "gathering" and "splitting" in the same place, to get the necessary rise and round of the beds. After this the ground is well rolled, harrowed, seeded, and rolled again. It then remains to draw out the feeders on the crowns of the ridges, and the furrows in the bottoms between the beds. This is readily done by a single turn of the ridging plough. A man follows with a spade and gives the final touch up, and the work is complete. The expense of outside conductors, dams, and wears will not usually exceed a few shillings per acre.

Catch-work irrigation can be practised at very little expense. The cost of forming the furrows by the plough will not often exceed 5s. per acre, and very little spadework is needed. This is decisive in favour of catch-work, where it can be adopted. It also requires much less water, and is often fully as effective as bed-work irrigation. The furrows need to be but very small, as all that is required of them is to arrest the flow of the water, and cause it to spread out equally again in a thin sheet over the whole surface. The total cost of this system, including the expense of bringing the water to the field, need seldom be more than 10s. per acre.

In the foregoing cases nothing is supposed to be paid for the water itself; but in many countries the water rates are high for irrigating land; and it may also occur that there is considerable expense in raising the water and in bringing it to the land after the right to use it is obtained.

In France, where one cubic foot of water per second is used to irrigate 70 acres of land, as much as £100 is paid per cubic foot per second during the season; and the cost per acre varies from £1 5s. to £1 10s. annually.

"In Spain, the Iberian Irrigation Company makes a charge of about 30s. per acre, for twelve waterings per year, equivalent to a total depth of 33 inches of water over the entire surface irrigated.

"In Italy, the average cost of the water to the farmer is from £150 to £170 per cubic foot per second, equivalent to 11s. 6d. per acre for maize, 31s. 6d. an acre for meadows, and £4 an acre for rice."*

The same writer states that in California, Colorado, and other parts of the United States, the "actual cost" of irrigating land "has been found to range from so small a sum as $1 † per acre upwards. That is, a community of farmers, numbering some hundreds, may construct the necessary dams, canals, sluices, and feed-gates, to irrigate 10,000 to 50,000 acres of land at a total cost not to exceed $5 per acre, where the conditions of water-supply, character of soil, and surface of the land are favourable. . . . . This estimate will allow of substantially constructed works, which will require but little repair or renewal to keep them in permanently good condition. Large tracts of land have been supplied with water for irrigation at a much less cost than this, in some cases even so low as 25 to 50 cents per acre; but this cost covers only the construction of the main supply ditch, and not the interior ditches, which, to be permanent, should be well laid out and properly constructed. It is now sufficiently well known, however, that a supply of water for irrigation can be brought to and spread over a farm upon our dry plains at a total expenditure of capital per acre not any greater than the annual rent paid per acre for irrigating water in European countries."

Where the water used in irrigation has to be raised from wells by pumping, or other means, the working expenses will be much increased. In Behar, where well irrigation is common, and the water is usually

* Stewart, "Irrigation for the Farm, Garden, and Orchard."

† The American dollar is 100 cents; equivalent to 4s. 2d.

raised by bullocks working a rope and buckets, one pair of bullocks can, in hot weather, irrigate one-tenth of a beegah per day, and in cold weather one-seventh of a beegah (a beegah is about two-thirds of an English acre). This—allowing four annas* per diem, a low rate of hire, for two labourers; pair of bullocks, wear and tear of rope and buckets, &c.—would leave each irrigation to cost, in the hot weather, Rs. 2 8 0† per beegah, and in the cold weather Rs. 1 12 0 per beegah, *i.e.* from 6s. 10d. to 4s. 4d. per acre.

The crops are usually irrigated four or five times, so that, allowing each watering to cost only Rs. 1 8 0 per beegah, there is still, at lowest calculation, Rs. 6 0 0 per beegah, or about 17s. per acre, expended annually in the mere application of the water.

Canal irrigation costs very much less than well irrigation, where, in the latter case, the water has to be raised by artificial means.

* 1 anna = 1·4d. † 1 rupee = 22·4d.

CHAPTER XII.

SOURCES OF WATER-SUPPLY.

RAIN may be termed the direct source of water-supply, though rain itself is due to the evaporation which goes on from sea and land. The moisture which rises through the air is, in fact, equal to that which falls through it. Every drop of fresh water on the surface of the globe, or within the earth's crust, has been distilled from the atmosphere.

Rainfall.—For drainage works we require to know the maximum fall of rain during storms, but for water supply we must estimate the least quantity of fall.

The comparative quantity of rainfall depends upon the vicinity of mountain ranges, and not upon altitude. The greatest fall occurs in the west of hilly districts. In Great Britain it varies from 15 inches annually, in dry districts in dry years, to 150 inches in wet districts in wet years. In exceptional cases, near the Lake district, as much as 220 inches has fallen in one year. The mean annual rainfall in England is estimated at 32 inches.

Influence of Vegetation on Rainfall.—The fall of rain in any district increases with the increase of vegetation, and especially of forest growth. "Trees and forests," remarks Steinmetz, "contribute to the formation of springs and watercourses, not only by means of the humidity which they produce and the condensation of vapours by refrigeration, but also by reason of the obstacles which they present to the evaporation of the water in the soil itself, and by means of the roots which, by dividing the soil like so many perforations, render it more permeable and facilitate filtration. The clearing of forests, and the consequent drying up or draining of marshes and bogs, have caused a material alteration, not only in the entire face of the country, but in the supply of water to the rivers formerly derived from those reservoirs, and in the periodical amount of rainfall and the regularity of its distribution." In Germany it is considered that, in order to insure a regular and sufficient rainfall in agricultural districts, the proportion of forest or woodland should not be less than 20 per cent.

Springs.—One of the duties of rain-water is to replenish the deep-seated springs. This is done by that portion of the rainfall which escapes evaporation and drainage, and penetrates into the porous strata of the earth. And that it is the rainfall which is the immediate and only source of supply to all the subterranean reservoirs, as well as to all the surface streams and lakes, it would be easy to prove. It may be daily observed that springs increase or decrease in proportion as it does or does not rain; and if a drought occurs, of a few weeks' duration even, many of them go dry altogether. If the drought were protracted for a year or less, there would be scarcely any springs met with in all the land. The absence of rainfall has the very same effect in diminishing the water of lakes, and it tells far sooner in the flow of rivers.

Water-bearing Strata.—Although a considerable portion of the rain-water, perhaps one-fourth of the entire quantity which falls on the surface of the earth, penetrates its porous strata, and is gathered in subterranean recesses, there is no more a general distribution of water in the stratification below the crust of the earth than there is on the surface. Yet many thousands of pounds are annually wasted in fruitless attempts to get water where it does not exist.

Predictions of water being obtainable from subterranean sources at a given point on the surface can never be certain without a very thorough knowledge of the geological position, thickness, porosity, dip, and soundness of the strata over all the area that can have influence upon the flow of the percolating water. There are, of course, water-bearing strata; but though plenty of water may be got by sinking at one point, it may happen that only a few rods distant no water will be obtainable in the same stratum, an intervening *fault* having intercepted the flow and led it off in another direction. In one case, after trying a number of places for water, none was found within 120 feet of the surface, and yet close by water was obtained at 40 feet in depth. Sometimes, by the extension of a heading from a shaft in a water-bearing stratum, to increase an existing supply, a fault is pierced, and the existing supply led off into a new channel.

"The underground flow of water towards wells or springs is limited and controlled, not only by the porosity of the strata which it enters, but also by their inclination, curvature, and continuous extent, and by the imperviousness of the underlying stratum. The chalk and limestone do not admit of free percolation, and are unreliable as conveyors of water from distant gathering surfaces, since their numerous fissures through which the water takes its course are neither continuous nor uniform in direction.

"The mere distance from hills or mountains need not discourage us from sinking wells. Waters are sometimes gathered through inclined strata from very distant water-sheds, and sometimes their course leads under considerable hills of more recent deposit than the stratum in which the water is flowing." *

Commencing with the chalk formation downwards, Professor E. Hull has arranged twelve sets of strata according to their water-bearing quality. Of the twelve seven are permeable, or water-bearing formations, viz.:—(1) Chalk and Upper Greensand; (3) Lower Greensand; (4) Purbeck and Portland beds; (6) Coral Rag and Grit; (8) Oolite and Upper Lias sands; (10) Middle Lias; (12) New Red Sandstone, with a total thickness varying from 1,275 to 5,500 feet; while alternating with the above are five impermeable or dry formations, viz.:—(2) Gault clay; (5) Kimmeridge clay; (7) Oxford clay; (9) Upper Lias clay; (11) Lower Lias and Keuper marls, with a total thickness varying from 2,110 to 5,430 feet vertical.

The water-bearing strata, it is seen, consist of sandstones and limestones of various kinds; the dry formations of clays and shales. Yet the very same "strata that now throw out springs or yield water when pierced would, if occurring at a different level, or if inclined at a suitable angle, become the means of draining water away from other parts than that in which their waters are now collected. This follows as a matter of course, for the conditions would merely be reversed, and the water would pass through the beds

* Fanning, "On Water Supply."

in another direction, the springs of one locality being in fact but the natural drainage of another."

Effect of Drainage on Water-Supply and Floods.—Every inch of rainfall lost by drainage from every acre of ground represents a loss of 100 tons of water to that acre. The average loss of water by drainage throughout the country is probably half the rainfall, but taking it at 10 inches, then the loss will be 1,000 tons per acre, or 640,000 tons per square mile.

The modern system of drainage clears the land of its surplus water almost as soon as it falls, there being now few of the ancient surface reservoirs, in the shape of bogs and marshes, to receive and retain it for future use. It does not follow, however, that the subterranean reservoirs must suffer, because where there is a porous surface stratum (and it is the porous strata only that feed these underground reservoirs) the rain-water falling upon it will sink as before, until the level of supersaturation rises to the level of the drain-pipe, which will only carry off the surplus water.

The immediate effect of the drainage of higher lands has, however, often been to inundate the lower levels, by causing the watercourses of the district to rise more speedily and to greater height than before. But as the flow of the stream is more rapid, and the total volume of discharge is not augmented, the floods subside sooner.

Artificial Sources of Supply.—The foregoing considerations lead to the conclusion that, in all cases of artificial water-supply, it must be obtained from one of two sources—either from subterranean reservoirs, or from surface drainage—and that geological conditions will determine which of these sources can be made most available. Where water-bearing strata can be tapped, the supply may be obtained by sinking wells; but where the subjacent water-bearing strata lie so deep that the expense of a well would be too great, the supply must be obtained by artificial storage of rain-water and surface-drainage. These different means of obtaining water will be found treated of at length in the succeeding chapters.

The distillation of sea-water is said to be the only means of domestic water-supply in some districts of South America. For agricultural and farm purposes generally, even on the smallest scale, however, the distillation of water would be very far from economical.

Still there are times and places when men cannot afford to disregard any possible means of obtaining even a few drops of water. An Australian recently supplied himself with water in a very novel way, and saved his life by it, while crossing one of the waterless regions of that vast continent. This he did by thrusting the ends of green scrub-wood—"mallec scrub"—into the fire, and catching the sap driven out at the other end in a bark trough. He states that a dozen mallec sticks, 4 feet long and 2 or 3 inches in diameter, would give a pint of water in an hour; and suggests that the same device may possibly be found of vital importance to other bush-rangers and travellers in arid regions.

CHAPTER XIII.

WELLS AND WELL-SINKING.

WELLS are of three kinds:—1. Open Wells. 2. Bored Tube Wells, commonly called "Artesian Wells." 3. Driven Tube Wells, sometimes termed "Abyssinian Tube Wells." One or all of them may be *flowing* wells, or they may not. In the latter case, the water may rise to the surface or near it; but will generally have to be raised some distance by pumping.

Driven Wells, or "Abyssinian Tube Wells."—The newest system of obtaining water from subterranean cavities is by driving a tube into the ground until its perforated end reaches a stratum containing water. When that occurs, the water will immediately flow through the perforations into the pipe; and, if a pump is attached to the upper end of the tube, by pumping for a time, all the particles of sand and fine gravel will be drawn out, and the cavity thus formed around the perforations will remain filled with pure water, as shown in Fig. 23.

Mr. Robert Sutcliff* has given a good account of the process of driving a tube-well:—"In the first place," he says, "the materials used must be of the very best quality, and especially tough and good iron is required for the tubes. The first tube is pointed

* Annual Conference on National Water Supply, 1879.

and perforated up for a few inches, with holes varying from one-eighth to quarter inch. The point is somewhat bulbous; but only sufficiently so to make clearance for the sockets, by which the tubes are connected together. On the tube a clamp is fastened, provided with steel teeth, so as to grip the tube. This clamp is tightened by means of two bolts. Next, a cast-iron driving-weight, or monkey, is slipped on to the tube, above the clamp. The tube, thus furnished, is stood up perfectly vertical, in the centre of the tripod; ropes are made fast to the monkey, and driving is commenced by two men pulling the ropes, and allowing the monkey to fall on the clamp. It is particularly important that the bolts of the clamp are kept tight, so that no slipping takes place. When the pointed tube has so far penetrated the earth that the clamp reaches the ground, the bolts are slackened, and the clamp raised again some two or three feet. Length after length of the tube is thus driven into the earth, being connected together by socket-joints. It will be noticed that the tube well proper is, therefore, self-boring, and that no core of earth is removed.

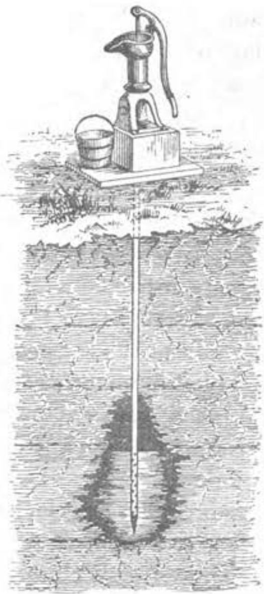


Fig. 23.

"One of the first questions that will suggest itself to a thinking mind is, will not the small perforations be entirely blocked up by being thus forcibly driven through the earth? This was the American's first idea, and he provided a sort of sleeve, in the shape of a sliding-tube, over the perforations, to protect them from the earth. Experience, however, has proved this protection to be quite unnecessary. The perforations are made about four times as numerous as is necessary for obtaining a full flow of water from the tubes. Earth does find its way into the tube wells in pellets, like the casts from a worm; but some of the perforations are always left sufficiently open to allow water to pass into the well; and, if the soil comes rapidly into the tubes, it is easily mixed with water poured down from the surface, and drawn up by ½-inch tubes, to which a pump is attached.

In the Abyssinian and other campaigns, "the wells were only used singly, as one or two were found sufficient to supply the wants of a number of troops. When, however, large supplies for manufactories, towns, and villages were needed, a fresh development in the system took place. Instead of single wells of great diameter, groups of moderate size were driven, and coupled together by horizontal mains; so that powerful steam-pumps could draw from many wells at the same time. The great friction that would be caused by drawing an enormous body of water to a single spot is thus avoided. Wells so coupled draw from a very large area of ground, and the water-level at any one spot is not so readily lowered. The very action of the pump, too, in drawing the water to the wells, opens and maintains channels of communication which help to keep up the level of the water. In putting down plant for a large supply of water, a trench, hundreds of feet in length, and some two or three feet in depth, is dug; and tubes are driven every 20 feet, and coupled by mains as already described.

"It may be interesting to refer to some particular instances, where large supplies of water are thus obtained. At West Thurrock, in Essex, a cement company is pumping from two 5-inch tube wells, about 80 feet deep, 220,000 gallons per day of 10 hours. Another cement works at Northfleet is pumping 60,000 gallons per day. These have been pumped daily for about four years, and still give a constant supply. As expense is an important feature, it may be mentioned that the cost of these did not exceed £60 each. The coupled tube wells are to be found in greatest numbers at the centres of beer manufacture, where abundance of pure and cool water is an absolute necessity. At Burton-on-Trent about two million gallons are pumped daily from these wells.

"When rock, solid stone, or incompressible clay is met with, a tube cannot be driven through it without first making a hole and removing the cores. In some cases, however, there may be many feet of loose earth which can be easily driven through. The tubes, therefore, may be fitted with a temporary hard wooden point, which will allow them to be driven through the soft earth, and when an obstruction that cannot be penetrated is met the point is knocked out, and, being wood and in sections, it floats to the surface of the water and leaves an open-ended tube, through which ordinary boring tools can be passed to chisel and break up the rock. A tube can frequently be driven through gravel and clay to a depth of, say, 70 feet in a single day. To bore to the same depth in a similar stratum frequently takes ten days or a fortnight. The saving that may be effected by driving through the loose stratum can, therefore, be readily appreciated, and what is still more important, the upper part of the tubes are fixed more tightly in the ground than if a boring had been made to receive them. In some cases, however, hard strata come right to the surface, and the boring operations, consequently, cannot be deferred. When this is the case, instead of using a pointed tube, an open-ended steel-shod pipe is driven into the hole as the boring proceeds. As the tools pass down inside the pipe they do not cut so large a hole as the outside circumference, and some little trimming down of the sides is left for the steel shoe to perform.

"In great depths the single tier of pipes with which the work is commenced cannot be forced the whole way. Tubes, therefore, of smaller diameter are inserted; but, as to pump by the tube-well method air-tight joints are absolutely necessary, the final tube is continuous from the deep spring to the surface. In this way tube wells 300 and 400 feet in length are put down, and if the spring, when tapped, rises to the surface, or within, say, 25 feet of it, only an ordinary lift pump is required to obtain the supply. Where the water does not rise to the required height, a deep-well pump can be lowered into the tube well, and worked by rods from the surface."

The latest method of driving tube wells is more particularly applicable to tubes of large size, and is so simple as to merit a brief notice. "An elongated cylindrical weight passes down inside the tube, and the blow, instead of being struck at the surface, is delivered where it is wanted, near the point which penetrates the earth. As water in the tube would impede the force of the blow, the first socket above the perforations is made sufficiently long to admit of a stout iron ring or washer being placed in the centre of it in such a way that the two lengths of tube, when screwed tightly together, butt against it, one on the under, and the other on the upper surface. The interior of this ring is of sufficient size to allow the water to pass freely through it, but it has a screw thread cut throughout its whole length. During the operation of driving, the opening in this ring is closed by a steel plug, which is screwed down into it until its shoulder butts on the ring. The upper surface of the plug forms an anvil, on which the driving weight falls. The plug is readily removed and brought to the surface when the required depth has been reached."

"Artesian," or Bored Tube Wells.—Where driven tube wells are not practicable, from the nature of the strata which have to be passed through, artesian wells may be attempted. These are simply open-ended steel-shod pipes, which are driven down after the drill as it bores through the rock, the core of earth at the same time being brought to the surface.

The term "artesian" is only properly applied to wells in which the water rises to or above the surface. But many so-called artesian wells are not "flowing" wells, the water supplied by them having to be raised partly by pumping.

Self-flowing wells and springs are similar in action, and their principle is this: water percolating through pervious strata, such as sand, gravel, or chalk, is finally arrested in its downward course by an impervious stratum of rock or clay, causing it to accumulate in the pervious strata above as in a reservoir, and when the source of supply is higher than the ground at the place where the well is bored, the water will rise to the surface, or even considerably above it.

The process of sinking artesian wells of great depth is attended with considerable difficulty and expense, but in many cases it is not necessary to go very deep. There are cases on record where a couple of men have completed a flowing artesian well in a few hours, and the tools used were carried on their backs. For larger operations a steam driller may be necessary, but smaller sets of the same machinery are made for working by horse, and even by hand power.

Some soils are easier operated in than others, but when the depth is not very great, if no rocks or boulders are met with, there will be no difficulty about the sinking.

In some formations—such as granite, hornblende, and limestone—artesian wells are not generally successful, unless water is reached before touching the solid rock. Where rock has to be passed, the expense is more and water uncertain, unless the geological conditions of the district are well understood.

"Among the causes of the failure of artesian wells," says Mr. Spon, "we may mention those numerous rents and faults which abound in some rocks, and the deep ravines and valleys by which many countries are traversed; for when these natural lines of drainage exist, there remains a small quantity only of water to escape by artificial issues. We are also liable to be baffled by the great thickness either of porous or impervious strata, or by the dip of the beds, which may carry off the waters from adjoining high lands to some trough in an opposite direction—as when the borings are made at the foot of an escarpment where the strata incline inwards, or in a direction opposite to the face of the cliffs."

The artesian well at Passy, for supplying water to Paris, is probably the largest well of the kind yet attempted. It is carried through the chalk into the lower greensands, which were reached at a depth of about 1,900 feet, the bore finishing with a diameter of 2 feet. The first water-bearing strata was reached at a depth of 1,894 feet, but the water did not rise to the surface. At length a true artesian spring was tapped at a depth of 1,923 feet, yielding 5,582,000 gallons per day. The total cost of the well was £40,000. It was laid with solid masonry to a depth of 150 feet, then wood and iron tubing was introduced to 1,804 feet from the surface, and below that there was a length of copper pipe pierced with holes.

There are, however, many deeper wells than that at Passy. The artesian well at Belcher's sugar factory, St. Louis, is 2,197 feet deep. It was finished in thirty-three months, at a cost of 10,000 dols. If report is true, the same American city can probably claim to have the deepest well in the world, for another artesian boring at St. Louis is said to have reached a depth of 3,850 feet, or 3,000 feet below the level of the sea.

Along the lines of the great railroads which now traverse the American continent, from the Atlantic to the Pacific, water is obtained at certain points by means of deep artesian wells for supplying the necessities of the roads. This, though often the only resource in the uninhabited and waterless districts passed through, is not successful at all places, and at hundreds of railway stations on these lines every drop of water they get, even for drinking and culinary purposes, has to be brought long distances by rail on special water-trains, which it is incumbent to run once or twice a day for that purpose.

During the autumn of last year we spent several weeks on the Texas Pacific and the Southern Pacific Railroads, and the lands immediately adjoining them; and, west of the Pecos river, at least, at all the stations along these routes, took notes of what had been done, or was being done, in order to obtain a sufficient water-supply. Thus, at Wild Horse Station, on the Texas and Pacific road, we found two wells had been bored, and plenty of water obtained in both, at a depth of 350 feet. Ten miles farther on, at Van Horn Station, a depth of 750 feet was reached before obtaining water. None of these wells, however, are self-flowing, and pumping-engines of about 35 horse-power, with two men in attendance, were employed at each of them for raising the water.

At Haskell Station, on the Southern Pacific road, and only eight or nine miles south of Van Horn, a boring had been made to the depth of 1,200 feet without finding water. At Sierra Blanca, forty miles farther west, where the two roads unite, water had not been found at a depth of 700 feet. At Finlay Station, twenty-one miles west of Sierra Blanca, the boring had been stopped at 200 feet without any signs of water.

A similar record could be given as the result of borings at more than a dozen other stations on the railways skirting the upper valley of the Rio Grande.

At the time of our visit, the prices being paid for boring were at the rate of $3 per foot for the first 100 feet, increasing half a dollar per foot every 50 feet beyond that depth. The bores were generally 7½ inches in diameter.

Ft.		Ft.	dols.	cts.		Ft.		Ft.	dols.	cts.	
1	to	100 =	3	00	per foot.	550	to	600 =	8	00	per foot.
100	,,	150 =	3	50	,,	600	,,	650 =	8	50	,,
150	,,	200 =	4	00	,,	650	,,	700 =	9	00	,,
200	,,	250 =	4	50	,,	700	,,	750 =	9	50	,,
250	,,	300 =	5	00	,,	750	,,	800 =	10	00	,,
300	,,	350 =	5	50	,,	800	,,	850 =	10	50	,,
350	,,	400 =	6	00	,,	850	,,	900 =	11	00	,,
400	,,	450 =	6	50	,,	900	,,	950 =	11	50	,,
450	,,	500 =	7	00	,,	950	,,	1000 =	12	00	,,
500	,,	550 =	7	50	,,						

At the above rates the cost of a well 1,000 feet would be $7,255. These prices, however, only included labour, the railway companies finding tubes, tools, engines, and fuel, &c.; so that the total cost must have been considerably greater. An engineer in charge of the boring at one of the stations told us that, making allowance for accidents, the actual total cost of one of these wells would be nearly double the above sum.

At Chicago, where there are upwards of twenty artesian wells, varying in depth from 1,200 to 1,640 feet, the average cost was found to be $6,000 for a 5½-inch bore, and $5,000 for a 4½-inch bore, in each case 1,200 feet deep.

No doubt, where the bore is less than 100 feet in depth, it can be done at a small outlay. We have heard a practical man say that, in easy working soil, it would then be profitable at $1 a foot; and that the tools and entire outfit for sinking such a well need not cost more than $75. The tubes would cost about 15 cents a foot.

As to the cost of boring artesian wells in England, we will quote Mr. Spon: "Boring," he says, "is usually executed by contract. The approximate average cost in England may be taken at 1s. 3d. a foot for the first 30 feet and 2s. 6d. a foot for the second 30 feet, and continue in arithmetical progression, advancing 1s. 3d. a foot for every additional 30 feet in depth. This does not include the cost of tubing, conveyance of plant and tools, professional superintendence, or working in rock of unusual hardness, such as hard limestone and whinstone."

Open Wells.—All the old domestic wells are of this class, and have been formed by digging or sinking a shaft of several feet in diameter. Owing to the great expense of doing this they are naturally of very limited depth as compared with the tube wells we have previously been discussing, few of them exceeding 60 feet, and the majority of them probably not reaching half that depth.

Very few open wells are now dug. Besides the question of greater expense, there are many objections to them, which the deeper tube wells are free from. In many cases the open wells are merely catch-water tanks, and even where water does rise in them from below, it is liable to be spoilt by the drainage from the surface carrying organic matters into the well.

In sinking a well of this kind the top waters, to a depth of 10 or 12 feet, should be carefully stopped off by solid masonry or hydraulic cement, and means adopted for keeping it free from contamination.

The water is raised in many open wells by pumping, but the old plan, which is still extensively in use in rural districts, was to *draw* water from the well by means of a rope and bucket.

The cost of digging a well in a clay soil, and building a well ring, say 3 feet in diameter, will be about £10 for the first 20 feet in depth, the expense increasing considerably in proportion for every foot of additional depth. This is exclusive of winch or pump, &c.

CHAPTER XIV.

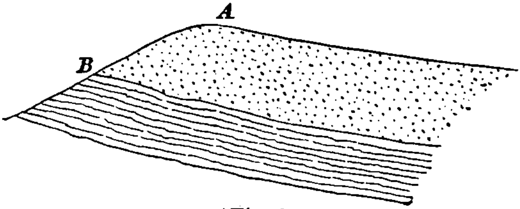
CATCH-WATER RESERVOIRS.

In cases not admitting of supply by means of wells, and where springs do not appear on the surface, the fluctuation of the rainfall, and consequently the flow of streams at different seasons of the year, require almost invariably that there shall be artificial storage of winter rainfall for summer use. When the mean annual requirements, whether for domestic use, for hydraulic power, or for live stock and irrigation purposes, one or all combined, are nearly equal to the mean available rainfall, the question of storage becomes of supreme importance.

Determination of available Rainfall.—For measurement of rainfall two kinds of data are required: (1) drainage-area, catchment-basin, or gathering-ground; (2) depth of rainfall.

Drainage areas are usually bounded by water-shed lines. The water-shed does not always, however, prove the drainage boundary; as, for example, when a porous superstratum overlies an impervious stratum. In such cases the drainage boundary will not be at A but at B (Fig. 24). Artificial watercourses and drains may also lead the water away from its natural course; but while this will diminish the yield of one water-shed, it will add to the natural supply in another place.

Steep rocky surfaces, or clay soils, make the best gathering-grounds, as the rain-water flows rapidly off them and less is lost both by evaporation and absorp-



[Fig. 24

tion than on flat and porous surfaces. Sand, gravel, and chalk, as well as many of the softer sandstones, are all so exceedingly absorbent that the rain is swallowed up as fast as it falls on them.

We have, then, only this general rule: Water-shed lines are the boundaries of the basins, but geological features may affect the quantity as already described.

The available rainfall of a district is that part of the total fall which remains to be stored or carried away, after deducting the losses by evaporation, percolation, absorption by plants, and other causes. The proportion which this bears to the total rainfall varies very much, being affected by the distribution of the rainfall, the porosity of the soil, the steepness or flatness of the ground, the nature and quantity of vegetation upon it, the temperature and moisture of the air, and other circumstances. Upon average drainage areas, and including floods and flow of springs, it may ordinarily be taken at about 50 per cent. of the annual rainfall. For different surfaces its ratio is more approximately as follows:—

On primary rocks . . .	nearly 1·
On moorland and hill pasture . . .	·8 to ·6
On cultivated land	·5 ,, ·2
On chalk ditto	0.

Assuming then that half the rainfall can be made available for storage, a fall of 32 inches per annum leaves us 16 inches, or 16·16 tons per acre.

But there are losses incidental to storage which must not be overlooked. Reservoirs constructed on the surface of the ground are seldom perfectly water-tight, and a certain amount of percolation is almost inevitable. More or less evaporation will also take place from the surface of the reservoir. The amount of evaporation from the surface of water has, in England, been found to be 18 inches or more per annum; but the percentage of storage water lost by evaporation will of course depend on the superficial area of the reservoir, and in any case will be comparatively small. If these two losses, however, taken together, amount to 6 or 7 per cent. of the reservoir water, it takes 1 inch off the available rainfall, and leaves us with only 15 inches available for consumption.

When water is impounded in manufacturing districts, it is common to allow from $\frac{1}{4}$ to $\frac{1}{3}$ of the available supply to the riparian owners, leaving $\frac{3}{4}$ or $\frac{2}{3}$ for the impounders.

Site of Reservoir.—This should be carefully chosen in regard to the gathering-ground, the nature of the surrounding and underlying soil, the requirements of live-stock, irrigation, and agriculture in general, as well as the cost of construction. The most favourable site, as affecting cost, is where a comparatively small embankment, thrown across a gorge or valley, will form a large reservoir with the water retained on three sides by the rising ground. An impermeable clay surface is as important as the configuration of the ground, as it not only influences the cost of puddling, but the proportion of the rainfall which can be collected, and also its retention in the reservoir is largely dependent on this feature. The position of the reservoir for supplying grazing stock with water, or for irrigation or other purposes, is of less consequence than obtaining a good storage, unless the reservoir is so distant from the place of consumption that the cost of delivery pipes would defeat the object of storage altogether.

Capacity of Reservoirs.—As a matter of economy, it will always be better to construct one large reservoir than two smaller ones to hold the same amount of water; but there is of course a practical limit to the height of the dams. Deep open reservoirs, however, are in all cases preferable to shallow ones, for other reasons besides that of first cost; for where the surface is large in proportion to the capacity of the reservoir, the greater will be the evaporation, and shallow water also encourages the growth and decay of vegetable matter.

Construction of Reservoirs.—Small reservoirs, such as would generally afford sufficient supplies for all agricultural purposes, need entail only a moderate amount of engineering skill and of pecuniary outlay. Where a ravine or gorge can be converted into a storage reservoir, no excavation will be needed, and the only expense will be that of constructing the dam, unless the bottom requires puddling. In such situations, however, the dam must be of great weight and strength as well as height.

The Texas and Pacific Railway Company conceived the idea of obtaining a large water-supply from a reservoir of this kind, near Carisso Pass, where the position was favourable for forming a lake basin of very large area. At a point where the gorge between two mountain ranges narrows to a width of perhaps 60 yards, an embankment, some 75 feet wide at base, 20 feet at top, and 24 feet high, was thrown across it. Riding over the waterless prairie, some miles to the south of this spot, we noticed the artificial mound, and guessing its purpose, was lured out of our way, partly through interest in the scheme, and partly that we might quench our thirst in the cool and pleasant waters of the imaginary lake which was in hiding on the other side. But not a single drop of water was there! The scheme had been carried out regardless of geological conditions, which, on the gigantic surface of the lake (that ought to have been) there had been no attempt to rectify by art. The floods had been there in their season, as was attested by the water-mark on the inner side of the embankment, and the embankment had stayed the torrent of water which had rapidly arisen behind it; but the basin of the reservoir was sandy and porous, and appearances too plainly showed that the whilom lake had vanished underground, when the floods were over and the dry season set in.

In some places a natural hollow exists, which, with very little excavation, can be made to form a capital reservoir. A reservoir on level ground will entail more labour; but it is not always necessary in this case even that the entire capacity of the reservoir should be excavated; for provided water can be led on from higher ground, a small portion of digging need only be done, and the excavated material used for raising the sides, making about two-thirds of the capacity due to embanking, and only about one-third to excavation. The principle of this reservoir is, however, objectionable, owing to the sides being raised so much above the natural level of the ground; so that, even where it could be filled to that raised level, it may be better to excavate to the full extent if necessary.

An excavating scoop, which is manufactured by Messrs. John Fowler and Co., will be found to greatly facilitate and cheapen the construction of these reservoirs. The implement in question was originally designed for making large ponds or reservoirs on Australian sheep farms; but its successful employment for this purpose has led to other application of it, and it is now used for other descriptions of excavating work, and particularly for levelling land and constructing dams. The scoop is worked by drawing it backward and forward between two steam-ploughing engines, in the same way as the implements employed in the double-engine system of steam-ploughing tackle, the engines being placed one on each headland, and the implement being pulled backward and forward between them. The scoop is, however, always filled by one of the engines, the other engine being used only for pulling the loaded scoop to the point where it is required to discharge. By ploughing the ground first, and using the scoop after, an extensive basin can soon be scooped out on the levelest surface; the depth being determined by the number of times the operations of ploughing and scooping are repeated.

Where the bottom of the reservoir is of a porous nature, it should be puddled to make it retain water. Where clay is not available for puddle, all that is necessary is to cover the bottom with loam to the depth of 12 or 18 inches, and then puddle or work this well with water till it will allow none to percolate. This working, or puddling, may be done by turning a flock of sheep or a herd of cattle into the bed of the reservoir to trample it well when wet. A similar practice is followed in India. When it is required to make the bed of a reservoir water-tight, they keep it wet and turn buffaloes into it, as their treading effectually puddles the bottom, and prevents water being lost by percolation.

In the construction of small reservoirs, and certainly of underground tanks, the use of concrete may be advisable. Common lime, properly slaked, and mixed with sand, if faced with cement, will make admirable tanks. Portland cement is a double silicate of lime and alumina, made from the deposits of chalk and alluvial clay on the shores of the rivers Thames and Medway, and possesses the property of setting and hardening under water. One barrel of Portland cement mixed with 16 gallons of water, if laid on half an inch thick, should cover 100 square feet of surface. One barrel of Portland cement and two barrels of clean sharp sand, mixed with 23½ gallons of water, should cover 219 square feet of surface to the same thickness; and one barrel of cement and three barrels of sand, with 28½ gallons of water, should cover 285 square feet of surface. The composition of cement and sand may be used if allowed to set before water is let into the work.

The mode to be employed in filling the reservoir, and the best means of providing for overflow, will be suggested by circumstances.

For drawing off the water from the reservoir, the employment of one or more large syphons will probably be preferable to making an opening in the embankment. On a level surface the water may have to be raised by pump, in order to distribute it by gravitation.

CHAPTER XV.

RAISING WATER BY MECHANICAL MEANS.

In irrigation works of any great extent the question of raising water by artificial means may be dismissed, as too expensive an undertaking for individual enterprise. Where, however, circumstances favour a unified system of irrigation, and the scheme is generally adopted by landowners or occupiers, and carried out as a public work under proper control, it may be otherwise.

In Egypt, for example, where some improvement of the present system is urgently called for, two schemes for improved irrigation by raising water by means of pumping are now under the consideration of the Government. The first of these, presented by the Minister of Public Works, proposes to fill the lesser canals during the dry season. The second proposal, which is favoured by the Public Works Company, is to keep the great summer canals perpetually full and to unify the canal system. The former project would be the less costly, and the amount requisite for it might, perhaps, be met by a slight increase in the land-tax on lands already watered, and a tax on lands expected to be reclaimed. In return, a partial exemption from the *corvée* would compensate the fellaheen from the increased burden. The latter scheme would call for a heavy outlay, but would abolish the *corvée* entirely; and, in the event of a deficit, the Government would endeavour to meet it by an extraordinary budget rather than impose a new water-tax. The experiment of artificially raising water by steam-pumping has already been tried in the province of Behera, with very discouraging results; but this is attributed to the bad quality of the machines. Before sanctioning either scheme, the Government will, probably, cause experiments to be made in one or two provinces.

As already remarked, however, where irrigation is a work of individual enterprise, it cannot be practised with profit on an extensive scale, unless the water is delivered by gravitation from an elevated canal, river, or impounding basin. As there are thousands of situations where the only source of water-supply is below the level of the land to be watered, the effect is practically to prohibit the artificial application of water to such lands on a large scale.

It is different in garden culture, and in market-garden farms, where the area of land under cultivation is comparatively small, and the value of the produce is far greater than in ordinary farming. The difficulties in the way of raising a sufficiency of water for irrigating garden crops in dry weather are not so insurmountable; and the expense will, in most cases, be amply repaid by the increased profits.

For other purposes than irrigation—the wants of live-stock, for feeding engines, and driving machinery, and for domestic purposes—though the need of water is greater, it is required in smaller quantities; and the cost of raising it, when the source of supply is below the level of the place where it is to be used, is then a subsidiary consideration.

As regards the most economical power and machines

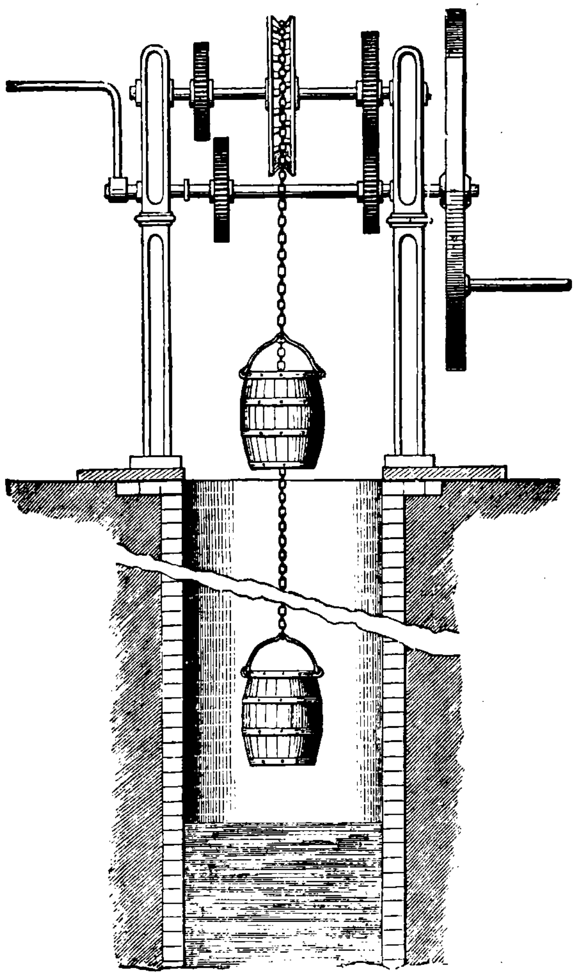


Fig. 25.

for raising water, much will depend on the height of the lift and the quantity to be raised. Hand or animal power, steam, wind, and water, are all employed as motive-powers for this purpose; and the instruments for utilizing the power so used vary from the primitive rope and bucket to the water-ram and the steam-pump.

For raising water from open wells, the rope and bucket is the most simple means. An improvement on the old mode of drawing by bucket is shown in Fig. 25, as designed and manufactured by S. Owen and

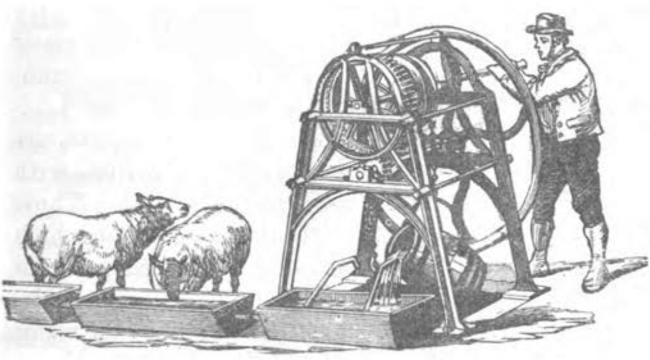


Fig. 26.

Sons, London, in which a windlass is erected over the well, and two buckets are in use, one filling while the other is emptying. Where required, a self-tipping apparatus is provided, with a cast or wrought iron trough, into which the buckets discharge themselves as they reach the surface. In Fig. 26, part of a series of troughs is shown connected together by short pieces of flexible or other pipe, so that any number can be filled for watering a large flock of sheep (as required in the Australian colonies, &c.), the man at the wheel keeping at his work while the self-acting apparatus fills his troughs. This apparatus for raising water is also largely employed for deep wells in many parts of

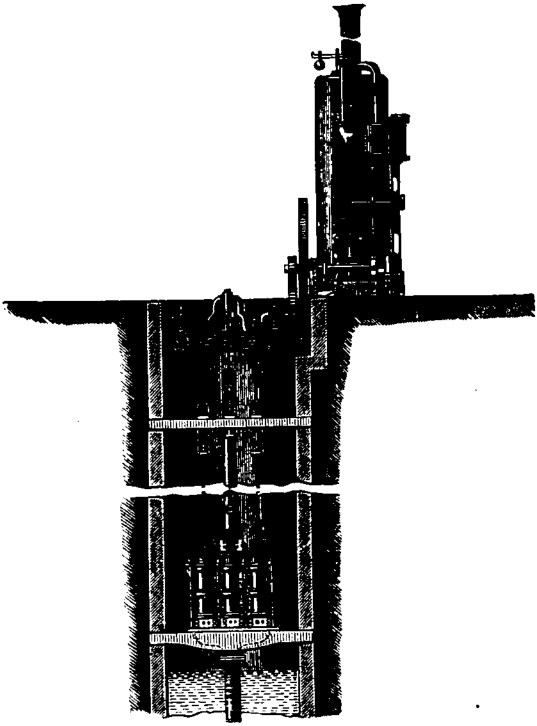


Fig. 27.

England where pumps would be expensive, and the labour required to work them great.

When a large and continuous supply of water has to be raised by this method, a pony or donkey may be employed to hoist the buckets. On the Continent, this mode is practised successfully, and the pony is trained to work without attendance.

Well Pumps.—The pump, however, is a more convenient instrument for raising water from wells than the rope and bucket. For low lifts, under 26 feet, the common suction, or lift pump, is sufficiently powerful; but for deep wells, force-pumps, or suction and forcing pumps, of the treble or double barrelled type, with valves in the buckets, and an additional retaining-valve for lifts over 100 feet, will have to be used. In these pumps the rods pass down inside the rising main pipes, which are of larger diameter than the working barrels, thus allowing of the buckets and valves being drawn up for repair through the pump-head or cover, which is fixed above the highest level to which the water is likely to rise under any circumstances. Without some such provision, access could not be gained to the working barrels and lower valves should they become immersed, or where they are confined in a small bore hole.

Fig. 27 represents a small steam-engine working a set of Warner & Sons' treble-barrelled deep-well pumps. The same class of pumps can be furnished for water, wind, horse, and even for manual power.

Where only small supplies of water are needed, the question of raising it from deep wells by manual power is, however, so difficult to arrange, that small motors, of one or more horse-power, worked by gas or hot air, are commonly employed, especially in country houses. They are more economical than steam, and do not require skilled labour.

Power required to raise Water from Deep Wells.—Appleby gives the following table of power required to raise water from deep wells by pumping:—

Gallons of water raised per hour ...	200	350	500	650	800	1000
Height of lift for one man, in feet	90	51	36	28	22	18
„ „ „ donkey „	180	102	72	56	45	36
„ „ „ horse „	630	357	252	196	154	126
„ „ „ H.P. steam-engine „	990	561	396	308	242	198

A good high-pressure steam-engine should raise 3,300 gallons 1 foot high per minute per nominal horse-power; the friction of the pump being compensated by the excess of the indicated power over the nominal.* The power required depends, of course, on the height to which the water has to be raised.

Rule for finding required Horse-Power.—For calculating the horse-power required to raise a given quantity of water to a given height, we have this general rule: multiply the weight in pounds of water to be lifted in one minute by the vertical height in feet, and divide by 33,000.

Example.—Find the horse-power that will be required to raise 2,000 gallons of water per minute to a height of 100 feet.

A gallon of water weighs 10 lbs. Therefore

$$2{,}000 \times 10 \times 100 \div 33{,}000 = 60{\cdot}60 \text{ H.-P}$$

Many engineers add one-fifth for friction. This would bring the required horse-power in the example up to 72·72.

Cost of Pumping.—Mr. Fanning gives the following among other examples of the cost of pumping water in various American cities by steam-power and by water-power:—

* Box, "On Hydraulics."

COST OF PUMPING WATER

Per Million Gallons in various American Cities in 1875.

City.	Power employed.	Lift in feet.	Millions of gallons pumped during year.	Pounds of coal per million gallons.	Cost of coal per million gallons.	Wages of labour per million gallons.	Cost of repairs per million gallons.	Cost of engine-man's stores and supplies per million gallons.	Total cost of pumping one million gallons.	Cost of raising one million gallons 100 feet.	Pounds of coal used to raise one million gallons 100 feet.
					dols.	dols.	dols.	dols.	dols.	dols.	
Brooklyn, N.Y. .	Steam power .	176·3	9998·00	2703	8·44	3 64	1·45	1·97	15·50	8·79	1533
Jersey City, N.Y.	,, ,,	160	4439·26	—	18·33	—	—	—	18·03	11·27	—
Chicago . .	,, ,,	120	10957·25	3095	8·91	1·59	·14	·21	10·81	9·00	2571
Indianapolis, Ind.	,, ,,	117	353·29	1697	14·11	16·01	2·31	3·12	35·55	30·38	1450
Montreal . .	,, ,,	165	1326·47	6204	16·08	7·86	·94	2·30	27·18	16·47	3760
Philadelphia .	Water power .	90 to 115	7670·1	—	—	1·57	·13	·39	2·09	2·15	—
New Haven .	,, ,,	115	1769	—	—	1·00	—	·33	1·33	1·16	—
Manchester . .	,, ,,	113	424	—	—	2·60	·16	1·30	4·06	3·59	—
Montreal . .	,, ,,	165	1879·56	—	—	·76	1·33	1·33	3·42	2·07	—

Centrifugal Pumps.—For raising a large volume of water to a moderate height this class of pump is invaluable. The limit to which it can be economically employed depends upon circumstances which are constantly varying. It is used to raise water to a height of 40 or 50 feet at times, but is best adapted to lifts not exceeding 25 feet.

An advantageous arrangement is to work these pumps

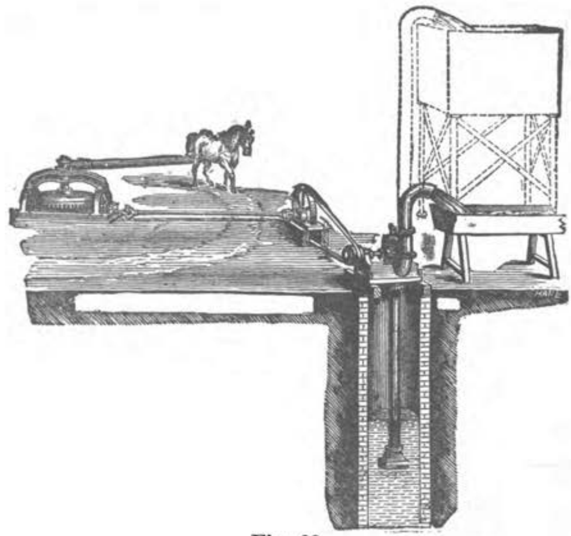


Fig. 28.

by a portable engine, as not only can both the engine and pump be placed in any position most suitable for working, but when not required for raising water the engine can be easily detached, and applied to any work for which portable engines are adapted—such as sawing, threshing, grinding, &c.

On low-lying lands an engine and pump of this class is invaluable for draining, as well as irrigation purposes. The smaller sizes are adapted for being worked by horse-power or by bullocks. Fig. 28 shows a pump of this kind being worked by a horse. It is manufactured by Messrs. Hornsby & Sons, Limited, Grantham.

The following table gives the nominal horse-power required for the discharge of given quantities of water with lifts of 10 and 20 feet:—

Diameter of pipe.	Gallons discharged per minute.	Nominal H.P. required for a 10-foot lift.	Nominal H.P. required for a 20-foot lift.
Inches.			
3	100	1	2
4	200	1½	3
5	350	2	4
6	500	2½	5
7	750	3	6
8	1,000	4	8
10	1,500	6	10
12	2,300	8	14
14	2,800	10	16
15	3,300	12	20
18	6,000	20	35

Wind-Power.—The objection to windmills in drainage works was, that this power was too variable to be relied upon for keeping the water down to a certain level. There can, however, be no such objection when windmills are employed to raise water from wells for irrigation purposes, or for watering live stock, if storage reservoirs are provided equal to, say, a week's supply. By this means the wind can be utilized whenever it blows, and none of the water is wasted. The windmill works night or day, as called upon by the passing breeze; it wastes no water, requires no fuel, and needs no attendance. There are few field-pumps that might not be effectively worked by a small windmill, and a larger one will many times furnish a full water-supply for every purpose on the farm. Where water has to be raised for gardens, a windmill is indispensable. On the dry plains of the far West, too, where deep wells have

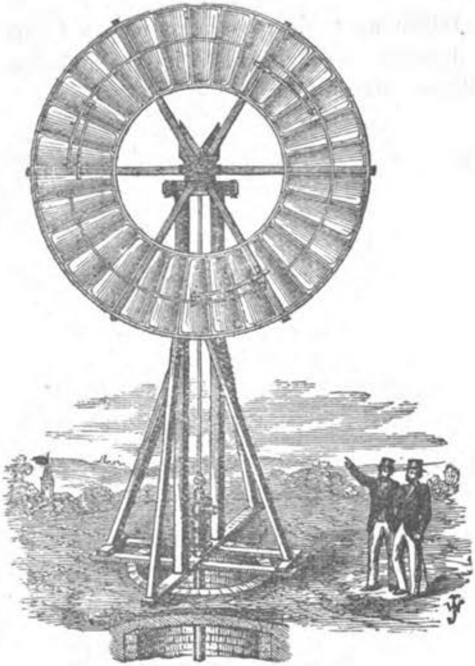


Fig. 29.

been sunk, but are not self-flowing, the windmill is the only means of economically bringing the water to the surface, and of enabling stock-grazing to be carried on with success and profit. The wells may be many miles from the homestead, but a windmill-pump will keep up an unfailing supply of water without the daily attention of the stockmaster, and at no cost for wages and fuel. Fig. 29 represents a windmill working a well-pump, as erected by J. Warner & Sons, London.

Self-regulating windmills are now made of two kinds. In one kind the circle of fans faces the wind at all times, but their angle to the wind is changed with its force. The other is the "solid wheel," the fans being all fixed, which swings round with its edge against the wind, when it becomes violent, by a self-regulating arrangement, which is partly effected by the centrifugal force of weights, and partly by the direct pressure of the wind. In the former, the self-regulating contrivance is as follows: When the mill begins to run too fast it pumps water rapidly into a chamber or cylinder, and this increase of water moves an arm, which turns the fans edgewise to the wind. When the wind slackens, a reverse movement takes place. By these arrangements the mills are rendered perfectly safe even in a gale of wind. Both these forms are well adapted to farm purposes and pumping water for cattle. They are made of various sizes, and range in price from £10 to £200.

Water-Power.—Water, like wind power, is more economical than steam power for pumping purposes when it can be conveniently employed. Our illustration (Fig. 30) shows an overshot water-wheel, by S. Owen & Sons, London, working a set of treble-barrelled pumps for the supply of a farm, &c., where a large quantity of water is required. In other cases, breast or undershot water-wheels may be employed, and they can be worked with any water that is available. Mr. Wheeler gives an instance of a water-wheel working treble-barrelled pumps, for the supply of pure water for a mansion, homestead, gardens, stables, &c., the motive power being sewage; and in another case, where the water is taken from the duck pond, to pump pure water from the well. The wheels and pumps cost from £76, for supplying 1,700 gallons a day, through 1,200 feet of inch pipes, with 90 feet lift, the fall for working

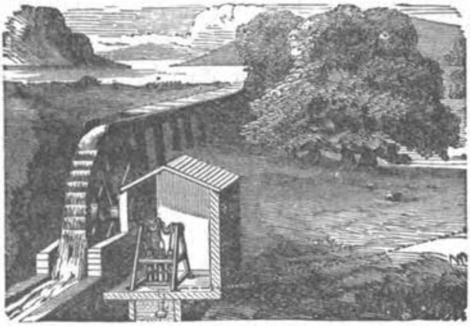


Fig. 30.

the wheel being only 5 feet; to £133 for supplying 1,200 gallons through 1,600 feet of piping, with 165-feet lift. Mr. Clutton states that the cost of fixing water-wheels 8 feet in diameter, in the neighbourhood of the Cotswold Hills, for the supply of farm premises and cottages, was from £55 to £70.

Noria, or Persian Wheel.—Markham* thus describes the use of the Noria (Fig. 31) in Eastern Spain, for raising water to irrigate terraced fields on different levels above the canal: "These norias are of extreme antiquity, having been used in one form or another from time immemorial by Eastern nations. A deep channel is cut from the canal, over which a huge timber wheel is placed, upwards of 15 feet in diameter. By its side are two stone pillars supporting a cross-beam,

* "On Spanish Irrigation."

to the centre of which an upright beam is attached. This upright beam is the axle of a double wheel working horizontally, the two parts being joined by strong battens which lock with cogs in the great wheel. A long pole is fastened to the upper part of the upright beam, to which mules are harnessed and driven round. They move round the horizontal wheel, the battens of which

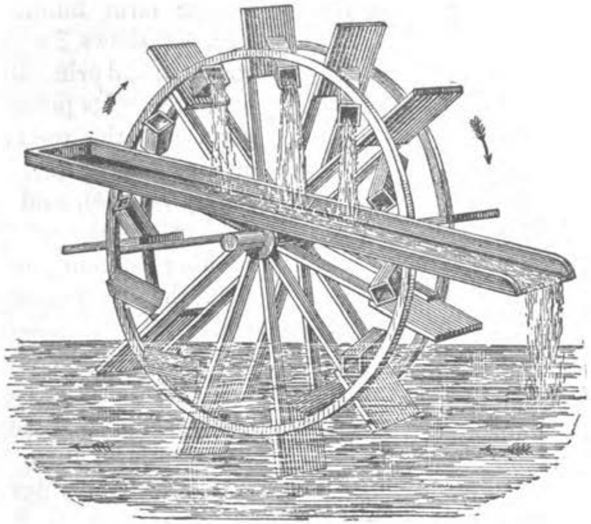


Fig. 31.

lock with the cogs in the great wheel and turn it round. The great wheel is fitted with a succession of boxes round the circumference, which fill when at the lower end of their revolution, bring the water up, and pour it into a trough leading into a channel. Thus the fields up to 15 feet above the level of the mother canal are irrigated. The upper channel brings the surplus water to another large wheel, which raises it in the same way to terraced fields at an elevation of 30 feet above the mother canal. The norias in Algiers and elsewhere are usually fitted with earthenware jars, instead of boxes round their circumference."

Hydraulic Ram.—The improved self-acting hydraulic ram is a highly useful and efficient apparatus, and is now much employed for raising water for such purposes as irrigating lands and supplying farm buildings.

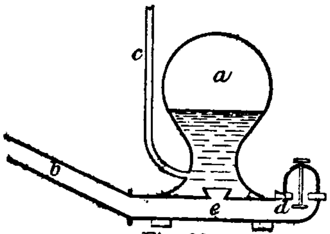


Fig. 32.

Fig. 32 shows its construction and principle of working. "Its principal parts are the reservoir or air-chamber (*a*), the supply pipe (*b*), and the discharge pipe (*c*). The running stream rushes down the supply pipe (*b*), and striking the waste valve (*d*) closes it. The stream being thus suddenly checked, its momentum opens the valve (*e*) upwards, and drives the water into the reservoir (*a*) until the air within being compressed into a smaller space by its elasticity, bears down upon the water, and again closes the valve (*e*). The water in the supply pipe (*b*) has, by this time, expended its momentum and stopped running; therefore the valve (*d*) drops down again, and permits it to escape. It recommences running, until its force again closes the water valve (*d*), and a second portion of water is driven into the reservoir as before—so it repeatedly continues—the great force of the compressed air in the reservoir driving the water up the discharge pipe (*c*)." It works day and night without needing attention, and will raise water to any height or distance, without cost for labour or motive power, where a few feet fall can be obtained. With the same quantity of water and fall to work it as the water-wheel and pump, the ram will send up double the quantity of water that the wheel will do, and to the same height. The ram is made in sizes to raise from 300 to 100,000 gallons per day, and will force to a height of 1,500 feet. It raises a part of the same water that works it, or will raise pure water from a well or spring, whilst worked from a stream of impure water. Our illustration (Fig. 33) shows a ram, erected by Messrs. S. Owen and Sons, supplied by a fall of water from a lake, and

Fig. 33.

forcing up to a farm at an elevation; the waste water expended in working the ram being carried off to a lower level and into the natural channel which the overflow of the lake finds for itself. It will work when quite immersed; its cost is small to begin with; it occupies but little space; and will work for years without once stopping or needing any repairs.

The hydraulic ram is applicable where no more than 18 inches fall can be obtained, but the greater the fall the more powerful the action of the machine, and the greater the elevation to which the water can be raised. If at all possible, a fall of 8 or 10 feet should be obtained. At the same time it is not advisable to use a greater fall than is absolutely necessary to raise the required quantity of water to the desired height, as the ram is then subjected to an unnecessary amount of work, the wear and tear of all the parts is increased, and the durability of the whole is proportionately decreased.

The proportion between the water raised and that running to waste depends mainly on the height of the spring or source of supply above the ram, relatively with the height to which the water is delivered. The quantity raised varies in proportion to the height to which it is conveyed with a given fall, and the length of the pipe through which the water is forced; the longer the pipe, the greater is the friction to be overcome. It is, however, not unusual to apply a ram for forcing water to a distance of 1,000 yards or more.

If the ram is fixed at a reasonable distance from the point where the water is to be delivered, the fall necessary to deliver a given quantity is approximately as follows* :—

About one-seventh part of the water will be raised to five times the height of the fall, and so on in the same proportion.

Thus, if the ram be placed under a head or fall of 10 feet, and the stream delivers 50 gallons per minute, about 7 gallons per minute can be raised to a height of 50 feet, or 3½ gallons to a height of 100 feet; or, in other words, an efficiency of 70 per cent. is obtained. Some of the improved forms of ram show, we believe, considerably greater efficiency than this.

The ram should be fixed in a pit 2 or 3 feet deep, sufficient to protect it from frost, and a race should be

* Appleby, "Handbook of Machinery."

cut to convey the waste water away. The pipes should also be laid at such a depth in the ground that they are out of the reach of the severest frost.

The cost of raising water by means of a hydraulic ram will depend on the quantity of water to be raised, the height to which it has to be forced, and the length of piping. Mr. Wheeler gives particulars of rams fixed for the supply of houses and gardens, varying from £92 10s., with a lift of 200 feet and 1,800 feet of piping, and yielding 1,400 gallons in 24 hours; to £26 for 273 feet of piping and 1,700 gallons.

CHAPTER XVI.

WATER-SUPPLY FOR LIVE STOCK AND FOR AGRICULTURAL MACHINERY.

In the earlier chapters of this work attention has been drawn to the need of water in the economy of plant life and growth, and to its use in irrigating land for the supply of those wants. The amount of water necessary for irrigation works may be greater than the requirements for other agricultural purposes, but assuredly not more important. For the live stock of the farm the need of water is more urgent than for irrigation, and the dependence of live stock on artificial supplies is more incessant. Whether in the fields or in the yards, water is a first necessity in summer, and also in the yards during winter. Only those who have had experience of stock-keeping on a large scale in waterless regions, where there is little or no rainfall during many months of the year, can realise the full importance of this part of our subject. The water-supply for agricultural engines is now only of secondary importance, and water-power for driving threshing or any other machines, if not an absolute necessity, is certainly a very great economy and advantage in many situations.

Water for Stock in the Fields.—A supply of good water for stock during the summer months is an essential requisite in all pasture fields. Horses and cattle require on the average about five gallons each per day, and a sheep about half a gallon per day in dry weather. On waterless formations, therefore, any means of rendering water easily come at does much to enhance the value of the land for grazing purposes.

The plans usually adopted are either to sink deep wells or to form reservoirs or drinking-ponds. If a well is sunk in the corner of a field where two fences cross, one trough may be made to serve for watering the stock in four fields; and if the well has plenty of water, pipes may be laid to carry part of it to other fields, which will be found cheaper than sinking more wells. When a pump is necessary, the water-trough for the stock should not be placed immediately under the pump-spout, but some feet distant, a piece of tubing being employed to convey the water. The pump itself should be fenced off so that cattle and horses cannot reach it.

Millions of acres in Central Australia, which for years have been considered uninhabitable, have been turned into fertile country by the aid of artesian wells and catch-water reservoirs. The country in parts is fairly watered, but wells are everywhere necessary to supplement the supply from the creeks. Those squatters who recognise this fact are doing well. The most valuable run, Tarella station, carries 60,000 sheep, the owner having constructed eight dams, averaging 10,000 cubic yards each, on the Bunker Creek. Not content with this, he sank three artesian wells at different spots, one of which is sufficient for the requirements of 20,000 sheep, whilst each of the others yields 3,000 gallons of water a day. A new artesian well at Sale, with its overflow of 400,000 gallons of water a day, rising 12 feet above the surface, is a great success. The recent sinking of an artesian well by Mr. De

Renzil Wilson, on Tatara Run, near Curriwillinghi, on the New South Wales side of the Queensland boundary, where at the depth of 200 feet a spring was tapped which forced itself to the height of 15 feet above the surface, and at the estimated rate of 500 gallons per minute, is even more successful.

Field ponds answer very well in localities where no other means of coming at water for stock is available. These are simply small reservoirs or receptacles for collecting water, and are dug out of the ground. They are usually made circular in plan, and so situated that they furnish a supply to four fields.

It need never be very difficult to make a pond in a clayey soil, which is itself retentive of water. Where ponds are made in a porous soil, much more care is necessary. The bottom and sides must then be covered with a thick coat of the toughest clay, from a foot to two feet thick, well rammed down. There is the greatest difficulty in finding water in chalky soils, because these are not in themselves very retentive of it, and generally lie in such beds that it is impracticable to dig through them. But even here ponds are easily made by digging into the chalk, and lining them with a coat of clay, as before directed. Some farmers judiciously pave the declivity by which the cattle approach the pond, and this renders it much more lasting than it would be, and preserves the water clean, while others pave the whole pond.

There are different methods of constructing ponds, but the plan adopted is generally this: The ground plan is circular, and usually 40 or 45 feet in diameter, with a centre depth of about 5 feet. This hole being dug out, a layer of clay, sufficiently moistened, is trodden down to the depth of a foot. Upon this a layer of quick-lime, an inch or more in thickness, is spread; and above that another layer of clay, a foot thick, is trodden and rammed as before. The use of the lime is to prevent worms penetrating through the clay in dry weather. A pond of the above dimensions will cost from £8 to £12.

Formerly the price of making a pond 60 feet in diameter was £10. A circle 60 feet in diameter contains an area of 314 square yards; so that each square yard of surface cost at this rate 7½d. And the capacity of such a pond, 6 feet deep in centre, is 209·4 cubic yards, each of which must have cost in the above instance 11½d. Five pounds have been given for a pond 36 feet in diameter, which is 10½d. each square yard of surface; and supposing it 4 feet deep at the centre, 2s. each cubic yard. It is plain from these figures that the larger the pond the less in proportion is the expense.

Water for Stock in the Yards.—Where a supply cannot be drawn from springs or running streams, recourse should be had to deep wells or to rain-water tanks. Ponds and open watering-places about the farmyard are very objectionable, as the water in them is always more or less polluted from yard drainage and from trampling by cattle. In many places driven or bored wells are now erected within the buildings, and even where the supply has to be brought a considerable distance from running springs, the employment of pipes enables water to be laid on to every stall in the yards if necessary, and at a comparatively small cost. The boon of this can only be appreciated by those farmers who have tried it. Not only is less labour entailed in tending the stock, but the animals themselves thrive better than when they are driven out to drink in all sorts of weather, and left standing in the pond, or hanging about the yard-gates to catch a chill.

The roofs of all farm buildings are, or ought to be, spouted; and if the rain-water from the roofs is collected, it will in most cases be found more than sufficient not only for the supply of the farm stock, but also for threshing purposes. Rain-water from the roofs, if stored in cool brick tanks, will keep sweet and fresh for any length of time and in any climate. We have pursued this plan in the tropics for a number of years, and though it was our only supply for domestic use, never had reason to complain of the water. Every 1,000 square feet of roofing, with a rainfall of 32 inches, will yield over 16,000 gallons of water per annum; and as the buildings on an average farm afford at least four times that amount of roof surface, it is evident there need be no lack of water about the farmyard. At the above rate, 4,000 square feet of roofing would supply 64,000 gallons of water per annum, or 175 gallons per day. But the consumption of water at the yards, on an average-sized farm, would be very much less than that. The cattle would be in the pastures all summer, and the horses also, perhaps; so that the summer consumption of water by live stock, in an ordinary farmyard, would never be likely to exceed 50 gallons per day. The brick tanks or cisterns should be large enough to contain a supply for eight months. Rain-water stored in barrels, especially open-headed barrels, is not fit for animals to drink. A plentiful supply of good water for live stock all through the dry summer weather, laid on both to fields and yards by supply pipes, troughs and ball cocks, instead of having to cart it very often from a distance, is so great a boon that no farmer would object to pay 5 per cent. on the necessary outlay.

Water for Agricultural Machinery.—Another reason for a good water supply to every field is the increasing use of steam power in cultivating the soil. Every acre of land cultivated by steam requires about 100 gallons of water for engine use. A 20-acre field requires 2,000 gallons. The convenience, not to say the economy, of having this supply at hand in the field itself is very great. On all recently laid-out farms, where steam cultivation has been introduced, much attention has been given to this point. Where springs, brooks, or drinking ponds are not accessible at every site likely to be occupied by the engines in cultivating an entire farm, tanks or wells should be provided. A tank placed in a corner where four fields meet would usually serve for all the fields, as in the case of a drinking pond so placed.

On the majority of farms, where the fields are tile-drained, the drainage-water may be led into tanks or cisterns and stored in sufficient quantity, not only for the use of the engines employed in steam cultivation, but also for watering the live stock, and sometimes even for working a water-wheel or turbine. Messrs. Howard, on their Bedfordshire farm, have so planned the drainage that it supplies a tank or pond at every point occupied by the engine engaged in tilling any part of the farm; and at the farmyard a reservoir has been excavated in the clay which holds half a million gallons of water. Extensive application of drainage-water has also been made on the estates of Lord Hatherton, in Staffordshire. In this case several ponds are used for storing the water, which is first carried to the farmyard and employed to drive a water-wheel which does all the threshing, &c., in addition to driving a saw-mill. After this, the water is passed to meadows on a lower level, where it is used in extensive and profitable irrigation.

CHAPTER XVII.

WATER-SUPPLY TO DWELLINGS.

IMPORTANT though it is to secure a good supply of water for irrigating crops, for watering live stock, and for driving machinery, the wants of the farmhouse itself, and of the cottages, are, in this respect, still greater. Water is one of the prime necessaries of life, and should be not only abundant but good. It is estimated that an adult consumes, on an average, about half an ounce daily for each pound weight of the body: therefore, a man weighing 150 pounds will require 75 ounces daily; about 50 ounces in drink and the remainder in the food. Unless, at the same time, the water consumed is good, a perfectly healthy condition of the system cannot be maintained; and it is well known that disease, in some of its most dangerous forms, is often introduced through the agency of bad water. Of course large supplies of water must be provided for domestic purposes beyond the quantities actually necessary to be consumed in food and drink.

Quantity required.—"The minimum quantity that is sufficient for the supply of a cottage or small farmhouse, for all ordinary domestic purposes, may be taken at 13¾ gallons per day, allowing 5½ persons as the average number to a house, and 2½ gallons for each person. This, of course, gives no margin for water-closets, baths, or other similar luxuries, which belong only to a larger class of dwelling. This quantity may appear small; but, having made extensive inquiry amongst cottagers and others, I found sufficient evidence to satisfy myself that it was the full quantity that was used when the water had to be baled or pumped from a tank, and not left to run to waste from a tap. Mr. Easton, in his evidence before the Select Committee on the Public Health Amendment Act of 1878, stated that, as the result of his experience and inquiries amongst cottagers in Sussex, he was satisfied that this quantity was sufficient. Colonel Cox put the quantity at 3 gallons a day, and the other witnesses agreed with the estimates of Mr. Easton and Colonel Cox, some even putting it at less. In the Sixth Report of the Rivers Pollution Commissioners is given an instance of four cottages, provided with a tank, in which the rain-water was collected from the roofs—one of the inhabitants being a laundress, who used a large quantity of water, and another feeding a number of pigs. The size of this tank was barely sufficient to give 10 gallons a day to each cottage; yet it is stated that it had never failed to maintain a sufficient supply.

"The large quantity used in towns—varying from 20 to 30 gallons a head—is due partly to manufactories, street watering, and flushing sewers; but, principally, to waste. This is proved by the fact, that towns supplied by meter do not average more than 7 gallons a head; and by the test applied to several streets in Brighton, where it was found that the supply did not average more than $4\frac{3}{4}$ gallons a head, although the number of persons to a house would be above the average, and water-closets and baths be freely used."*

Professor Rankine† gives as a fair estimate of the daily demand for water, per inhabitant, for different purposes, the following, based upon British water supply and consumption :—

	Imperial gallons per day.		
	Least.	Average.	Greatest.
Used for domestic purposes	7	10	15
Washing streets, extinguishing fires, supplying fountains, &c.	3	3	3
Trade and manufactures	7	7	7
Waste under careful regulations, say	2	2	2½
Totals	19	22	27½

Sources of Supply.—Water, as ordinarily used for drinking purposes, is obtained from either springs, wells, lakes, or rivers, or from stored rain-water or land drainage. Where none of the other sources are available, the rain-water falling on the roofs of the houses, if collected, filtered, and stored in underground tanks, will furnish an ample and perfectly good supply.

"Granting," says Mr. Wheeler, "that 2½ gallons per head per day is enough for all the ordinary domestic requirements of a cottage, sufficient rain falls on the roof of every house in the course of a year, if properly stored, to yield a full supply. A cottage with its outbuildings covers about 500 square feet of ground. Taking the rainfall at 22 inches per annum, the quantity that may be relied on as an average in the driest districts of the country, a slated roof will yield 5,700 gallons—nearly equal to a daily supply of 15½ gallons, or rather more than 2¾ gallons per head. Tiled roofs

* Mr. Wheeler, C.E., "Universal Conference on National Water-Supply," 1879.
† "Civil Engineering."

would yield less than this, being more porous than slates. Thatched roofs may be considered as altogether unsuitable for the collection of rain-water, from their absorbent nature, the difficulty of providing spouting, and the chance of pollution from the organic matter in the decaying straw."

Where rain-water from the roofs is the only supply, the minimum size of the tanks to be provided becomes an important question. It is usually reckoned that the impounding tanks or reservoirs should contain four months' supply in the rainy districts and six months' supply in the dry districts of England. Thus a tank for a cottage, where the daily consumption is 14 gallons, would require to hold from 1,680 to 2,548 gallons.

At the Reading Meeting of the Royal Agricultural Society of England last year, Mr. C. G. Roberts, Haslemere, Surrey, exhibited a very ingenious apparatus for collecting pure rain-water from the roofs of buildings. The apparatus, which is entirely self-acting, consists of a separator, the function of which is to reject the bad and store the good water, by preventing the first portion of the rainfall (which washes and brings down from the roof or gutters all kinds of impurities) from passing into the storage tank. The first water from the roofs when a shower falls is directed into the waste-pipe; then the separator cants, and turns the pure water into the storage tank. An illustration of this apparatus appears in the Journal of the Society, vol. xviii. part 2.

Impurities in Water.—Water may be very good for irrigation purposes and yet utterly unfit for household use. The most wholesome waters, as a rule, are spring water, deep-well water, and upland surface water; and the most dangerous ones are river water, to which sewage gains access, and shallow-well water. Stored rain-water, especially that gathered in large towns and cities, where smoke from innumerable chimneys taints the air, and the surface water from cultivated land, are of "doubtful" quality.

Rain-water is more pure than any other water before its descent, and it is only in large towns or cities where it becomes contaminated by atmospheric impurities, and is rendered unfit for use in the condition in which it falls. It is generally termed *soft*, in contradistinction to spring water, which is considered *hard*. The softness, which consists in a solvent action upon the fatty substance of the skin, is owing to a small amount of carbonate of ammonia, which is formed in the atmosphere and precipitated with the water.

Spring water and deep-well water, when impure, are usually so from the excess of inorganic matter, with which occasionally they rise highly charged. These admixtures are derived from the ground through which the water flows. The incrustations which form in steam boilers are caused by the precipitation of the impurities, in consequence of the concentration of the water in the boiler. They may be effectually removed, no matter what their nature, by boiling charcoal in the water, or by gently heating the water and filtering it through charcoal.

Pond water and shallow-well water is often full of animalcula, sewage, vegetable matter, sediment, &c.

The water from mountain streams and rivulets is always purer than that from low grounds, because the water from high lands runs rapidly, and generally over gravelled beds. River water from low grounds is generally rendered impure by the presence of organic matter generated in sewers and drains, and thence discharged. Almost every gallon of such water contains a quantity of spores, seeds, or ova of vegetable and animal organisms, and if a bottle of it is allowed to stand by for a short time a sediment is thrown down in which a number of creatures will be discovered by the microscope. Water of this sort is unwholesome and dangerous, whether it contains the actual carriers of disease or not.

Filtration.—In all towns where water-works exist the water supplied has already undergone filtration through sand and gravel, which is the only plan available for companies dealing with such immense quantities of water. One square yard of filter-bed should be provided for each 700 gallons required in 24 hours, and the filter-bed should be 6 feet in total depth, composed as follows: 30 inches of fine sand, 6 inches of coarse sand, 6 inches of shells, 30 inches of gravel. Perforated pipes should traverse the bottom of filter-beds to collect the filtered water, and the fine sand forming the top stratum should be frequently renewed.

The sand and gravel filter, however, is not sufficient, nor has it the power to remove a deal of the animalcula and other injurious matters often contained in the water. River water thus filtered may be none the less unwholesome because it is made clearer. Every one knows that the liquid evacuations of both men and animals is often clear, and can be readily passed through a stratum of coarse sand, but the liquid is not less free from sewage after being so passed. This filtration at best can only be looked upon as a means of removing the grosser impurities. It is therefore imperative that the water should undergo another and more complete filtering process before it can be considered fit for drinking, such as passing it through certain media which have the power of thoroughly purifying the water by oxidizing the organic matter and changing chemically the impurities in solution.

The Registrar-General most strongly recommends the adoption of a system of domestic filtration, every consumer employing upon his own premises suitable means to purify the water required for his use. He also recommends that householders should obtain real water purifiers, and not mere strainers. The old-fashioned system of passing water merely through balls or slabs of charcoal, or material which has the appearance of being charcoal, worked into a solid form, is for the most part useless for the proper filtration of water.

The best filters are constructed entirely with pure charcoal, and remove lead, lime, and sewage from water. They are also self-cleansing.

In Fig. 34 we have an illustration of Lipscombe's Self-cleansing Charcoal Cistern Filter. The drawing represents a filter and pure water reservoir inside an ordinary house cistern, but they may be modified to suit any cistern or tank above or under ground. The impure water passes through the inlet into chamber of filter, thence upwards through a plate, usually of porous stone, represented by the dotted line, then through powerful purified charcoal into the pure water reservoir, from which it may be drawn off cold by the pure-water tap, or hot and pure from the boiler.

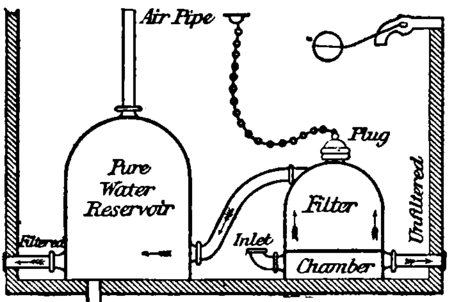


Fig. 34.

INDEX.

THE END.

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SCOTT'S FARM ENGINEERING TEXT-BOOKS

III.

FARM ROADS, FENCES, AND GATES

A

PRACTICAL TREATISE

ON

THE ROADS, TRAMWAYS, AND WATERWAYS OF THE FARM; THE PRINCIPLES OF ENCLOSURES; AND THE DIFFERENT KINDS OF FENCES, GATES, AND STILES

PREFACE.

ALTHOUGH roads and fences do not contribute directly to the revenue of the farm, and add very materially to the expenses, they are works of indispensable utility.

A judiciously planned system of farm roads enhances the value of the fields adjoining them, and without a sufficiency of fences the livestock of the farm could not be controlled nor the growing crops protected.

One of the most important items in large agricultural undertakings is the cost and facility of transport. It is every day becoming more essential to accomplish the removal of heavy crops and the application of heavy manures in the most expeditious way and at the cheapest possible rate. This can only be done where there is a well-devised system of well-kept roads, tramways, or waterways on the farm.

The subject of enclosures is an interesting one from many points of view, including as it does not merely the modern use of fences, but the ancient mode of marking the divisions of family estates (still practised by many of the modern nations of Europe) by boundary-stones or other landmarks, and the influence of enclosures and fences on shelter and climate.

Few non-agricultural readers would surmise that for every acre of enclosed land in this country there is over £1 invested in fences, and that the annual maintenance of these fences costs something like 3s. per acre.

Taking these figures in the aggregate, as applied to the 45,000,000 acres of enclosed land in the United Kingdom, their magnitude becomes at once apparent, for it shows the total capital sunk in fences to be nearly £50,000,000, and the annual maintenance and repair of these fences to cost at least £6,750,000.

There is no denying, however, that many existing fences might be dispensed with to the great advantage of agriculture, apart altogether from the expense of maintaining them.

The extended introduction of a cheap and durable system of wire fencing renders possible still further economy in the matter of fences. This is more especially true of barb wire fences, in which fewer lines of wire make an equally efficient fence, and that with only one-half to one-fourth the number of posts which it is considered necessary to use in plain wire fencing or in post-and-rail fences.

All the different kinds of fences now in use are noticed at such length and in such detail as their importance demands and the limits of the book admit.

CONTENTS.

LIST OF ILLUSTRATIONS.

FARM ROADS, FENCES, AND GATES.

CHAPTER I.

FARM ROADS.

Good roads are rarely met with on the farm. True, there are exceptional instances where the facilities afforded by a carefully designed and well-constructed system of roads have been attained, but such cases mostly occur under the immediate occupancy of an energetic and wealthy resident proprietor, or on the home farms retained by the proprietors of the larger estates. They do not, therefore, present any appreciable limit to our first statement, and are only to be regarded as examples of, and inciting to, a better than the prevailing state of things. On the majority of farms in this country, indeed, there is not a single furlong of *made road—i.e.* of road solidly constructed and kept in repair—except the comparatively short lengths leading from the public highways to the homesteads.

In an age of universal progress and advancement, the roads of the farm have received no general attention, and, indeed, are in little better condition than they were a century ago. It is not sufficiently recognised that the purpose of those internal communications is to reduce the cost of horse labour, and that a farm with a properly devised system of good roads is worth more to the occupier than it would be without such facilities.

Especially in clay-land districts, where good roads are most wanted, the majority of farms suffer from the narrowness and bad construction of the roads. There are many by-roads and lanes, over which there is much farm traffic at certain seasons of the year, that seem to be cared for by nobody. The result is that the harvest load may be seen fighting its way up the narrow lanes, while every hedge or tree takes a due tithe of the crop; or a good team is found pulling each other to pieces, with the wheels of the market-waggon or dung-cart nearly buried in the ruts of the road from the homestead.

Some lands there are, undoubtedly, so situated and of such a character that it would be superfluous to cut them up by internal roads; such, for example, where dry and flat grounds lie adjacent to or are bounded by public or occupation roads. It may then occur that the easy access to a good road and the contour of the field, together with the character and drainage condition of the soil, render the construction of roads inside the fences quite unnecessary. But that is not a very common occurrence, for even where a farm is well intersected by public or occupation roads, and the contour of the land flat, there will still be many fields which lie interior to those which abut upon the roads in question; and, wherever in order to reach one field another has to be crossed, it will always be advantageous to have a road. If there is much cart or waggon passage across a field, it will actually become an economy to devote a portion of the land to the purposes of a permanent road. Of course, where the ground is steep or otherwise naturally unsuited to farm traffic, it often becomes a first necessity to open it up by a substantial road, even though a good road runs across the outside boundary.

But we are not to be held as advocating the indiscriminate construction of roads. Far from it. We think that the fewer they require to be the better, for the first construction is very costly, and the labour and expense of maintenance is considerable, while they occupy a large amount of valuable land. Yet it is not too much to say that at every place where a necessity exists for a road, at such a place the needed facility should be provided. There should, indeed, be a well-defined and complete system of roads upon every farm, providing easy and ready access to every field without having to pass through another field. Every field should communicate with the road by its own gate, and have no dependence on any other passage. This convenience has not been sufficiently attended to; but it is equally necessary with the provision that each room of a dwelling-house should have an entry from the hall or passage without intruding through another room. This very necessary arrangement requires that a road passes between four fields in width, with two fields on each side of it, which open into the road from opposite sides, and it is convenient that the gateways terminate the headlands of the field, and have an entry at both ends —on the upper and lower headlands. At the same time, a gate must open from one field into another for convenience' sake, but not for a common thoroughfare; and it is then best placed at the end of the field, and in the line of the headland.

It is reasonable to suppose that with the introduction of heavy machinery—such as agricultural locomotives,

&c.—more general attention must be paid to farm roads, for a firm path is essential to the ready transport of these engines. But apart altogether from the requirements due to the introduction of heavy modern implements and machinery, it cannot be said that the permanent improvements on any estate or farm are complete without a definite system of good roads.

These roads, as being of the nature of permanent improvements, should be constructed at the expense of the proprietors, and maintained by the tenants or occupiers of the land.

The cost of such a system will materially depend upon the skill with which it is designed and laid out. It is surprising to any one who has never seen or attempted such a work with what economy it is possible to lay even a hilly farm under road control. And who can estimate the value of such a boon; the pleasure, the facility, and the profit derived; or the annoyance, the delay, the ruts, and the waste avoided thereby?

The important question, "What is the value of a farm with good and sufficient internal communication, and what the value of the same farm without any?" is answered as follows by Mr. J. Bailey Denton, in a paper on the subject of "Farm Roads," read by him before the London Farmers' Club some years ago. "Let us suppose," says Mr. Denton, "a farm of 500 acres, of a heavy clay soil, with the homestead in the centre, and good public roads on two sides of it. Five hundred acres will cover a square of seven furlongs on each side; and it would probably require two miles of road to give moderate accommodation to such a farm. This, at an average price of £5 a chain, will cost £800, and if we take the interest at £5 2*s*. 10*d*.

per cent. (the rate of instalment for repayment of principal and interest charged by the General Land Drainage and Improvement Company), the annual charge will be £41 2*s.* 6*d.* Is such a farm permanently improved by the acquisition of a road to the annual amount of £41 2*s.* 6*d.*, or 1*s.* 8*d.* per acre? When we consider that this annual sum of £41 2*s.* 6d. will barely cover the keep of one horse and a half, without regard to the wear and tear of the horse itself, and of carts, harness, and implements, I think we shall all answer in the affirmative. In such a farm of 500 acres, 400 acres being arable and 100 acres pasture and meadow, the produce of manure will be, under ordinary good management, from 1,400 to 1,500 tons of manure in the whole. This will suffice to give a dressing of 12½ tons to 116 acres, and the number of miles travelled in doing that will be 966, out and back, if we take the average road-lead to be one-third of a mile, or 27 chains. Now, if we remember that in heavy land we may not only pull our horses to pieces, but injuriously affect the land itself, if we do not take advantage of every hour of dry weather, but prolong the operation during wet weather, it is hardly possible to overrate the advantage of a hard road which will allow of a horse to travel at least 20 miles daily with the same ease that he will travel 12 or 13 miles doing the same work through clay mud. The difference of 28 days, which these figures show, in the time it will require to get manure on to the land, is one consideration which will go far to meet interest on the outlay of working the road, leaving out of consideration the injury done to tillage as well as damage to horses by carting over clay soils on wet days. If, therefore, we add all these advantages together—the gain in time, in power, in the wear and tear of carts and implements, and in the personal comfort of the occupier—there can be no doubt that 1*s.* 8*d.* per acre represents at least the value of the improvement in this assumed case; and we shall not be overstepping truth and practice in the resolution we may adopt if we assert, in general but decided terms, that the existence or non-existence of internal roads on a farm is an essential element in determining the rent that should be paid for it; and that the provision of farm roads, being a permanent improvement, and in the case of clay soils a very costly one, the outlay is properly a landlord's and not a tenant's duty."

CHAPTER II.

PRINCIPLES OF ROAD-MAKING.

"A ROAD, to be theoretically perfect," says Dr. Lardner, in his evidence before the Committee of the House of Commons, 1836, "should be, first, perfectly straight; second, perfectly level; third, perfectly smooth; and fourth, perfectly hard. If it possessed all these qualities in absolute perfection, the consequence would be that it would require no tractive power at all—an impulse given to a load at one end would carry it to the other by its inertia alone. This is the ideal limit to which it is the business of the road-maker to approximate as nearly as he can, all practical circumstances being considered. But, as it is obviously impossible to make roads in the country which would be perfect, there arises in most cases the extremely difficult inquiry as to the best possible compromise which can be made between all the inevitable imperfections the existence of which we are forced to admit."

Resistance on Roads.—The resistance or draught on roads is an important matter, a proper knowledge of which is of advantage in considerations regarding the gradients proper to be admitted in a line of road. It has been found by experiment that the resistance by wheel-carriages on roads is proportional to the load, and inversely proportional to the radius of the wheels.

The average proportion of the resistance to the load on a level part of a good broken stone road has been variously stated at from 44 lbs. to 75 lbs. per ton. Telford estimated it at $\frac{1}{30}$th of the gross load, or $74\frac{2}{3}$ lbs. per ton. That is to say:—

As the resistance : the load :: 1 : 30;

or,

$$\frac{\text{Resistance}}{\text{Load}} = \frac{1}{30} = \frac{74\frac{2}{3}}{2240} \text{ lbs.}$$

Sir John Macneil estimated the force required to move a ton weight on roads of different construction as follows:—

On a well-laid pavement	33 lbs
On a broken stone surface, having a bottom of rough pavement or concrete	46 ,,
On a broken stone surface laid on earth . .	65 ,,
On a gravel road	147 ,,

On an incline the resistance varies according to the sine of the angle of inclination, and we have this general rule for finding the amount of resistance to be overcome: To the known ratio of resistance of load on a level, add (if ascending), or subtract (if descending), the ratio of the rise to the horizontal length of the slope, and multiply by the gross load.

The result gives the resistance very nearly. Thus, for example, if we assume the resistance on a level to be $\frac{1}{30}$th of the load, the force required to draw a waggon of 3 tons weight along a level part of a macadamized road is $(\frac{1}{30}\text{th} \times \text{load}) = (\frac{1}{30} \times 6{,}720 \text{ lbs.}) = 224$ lbs.; but the force required to draw the same load on an incline of 1 in 60 is $(\frac{1}{30} \pm \frac{1}{60}) \times 6{,}720$, which gives 336 lbs. as the force to be exerted in ascending, and 112 lbs. in descending, the slope; while in a gradient of 1 in 30 the force required is $(\frac{1}{30} + \frac{1}{30}) \times 6{,}720 =$

448 lbs. in ascending, and $(\frac{1}{30} + \frac{1}{30}) \times 6{,}720 = 0$ in descending.

From these and such-like calculations we thus find that the comparative values of resistance to the same load on different slopes stand thus in ratio :—

Inclination.	Resistance.	
	Ascending.	Descending.
Level	1	1
1 in 60	$1\frac{1}{2}$	$\frac{1}{2}$
1 in 30	2	0
1 in 15	3	— 1
1 in 10	4	— 2

Consequently, if we estimate the tractive force which a horse is capable of exerting continuously at a steady walk at 112 lbs., each horse will be able to draw along a level a gross load of $(112 \times 30) = 3{,}360$ lbs. $= 1\frac{1}{2}$ tons ; while on an ascent of 1 in 60 a load of $(112 \times 30 \div 1\frac{1}{2}) = 2{,}240$ lbs., or 1 ton would be sufficient; and on an ascent of 1 in 30 the load, to be drawn with advantage, must not exceed $(112 \times 30 \div 2 =)$ 1,680 lbs. = 15 cwt.

From these results we observe that since the resistance is doubled by an ascent of 1 in 30, it will be exactly neutralised in descending a slope of the same inclination. Hence, if the gradient at any part is steeper than 1 in 30, there is a waste of mechanical energy in descending, because a retarding force must then be exerted, by means of brakes or otherwise, in order to prevent undue acceleration of speed. This is shown by a minus sign prefixed to the two last figures in the third column of the foregoing table.

These results establish the advantages arising from easy gradients, but, of course, the question of expense in excavating and embanking limits, in most cases, the flatness of the gradients, and farm roads especially are as much as possible constructed on the natural surface of the ground.

To put the case more tangibly, "We find," says Mr. Denton, "many farms abound in steep hilly slopes with inclinations of 1 in 30, or even steeper; and it has been practically demonstrated that the expense of power in £ *s.* *d.* required to draw a load of 1 ton along a common road of various gradients is 6*d.* where horizontal, to 8*d.* where there is a rising gradient of 1 in 30. If we adopt this comparison, we see that (all other points being equal with respect to formation and condition) the comparative saving of a level road over a rising gradient of 1 in 30 is 2*d.* per ton in the ordinary cost and application of horse labour on a farm."

At Bedford, in 1874, Messrs. Easton and Anderson tested the resistance to traction of agricultural carts and waggons by means of their new horse dynamometer.

The trials were conducted (1) along a hard road having a rise of 1 in 430; and (2) along an arable field of oat stubble, rather drier and harder than common, with a rise of 1 in 1000.

The fore wheels of the waggons averaged 3 ft. 3 in., and the hind wheels 4 ft. 9 in. in diameter, the width of the tires being 2½ and 4 inches. Empty waggons averaged about a ton in weight, and the loads were from 2 to 4 tons in a waggon.

The cart wheels were 4½ feet high, with tires 3½ and 4 inches wide. The weight of the empty carts averaged 10 cwt.; and the loads were 1 ton in a cart.

On the foregoing data, and with the speeds averaging 2½ miles per hour, the following results were deduced from the experiments:—

Description of Vehicle.	Draft on Road.		Draft on Field.	
	Total.	Reduced to a Level. Per Ton gross.	Total.	Reduced to a Level. Per Ton gross.
	lbs.	lbs.	lbs.	lbs.
Pair-horse waggon without springs	159	43·5	700	210
Four-horse ditto	251	44·5	997	194
Pair-horse waggon with springs .	133	34·7	710	210
One-horse cart without springs .	49·4	28	212	140

Line of Road.—The principal points to be attended to in selecting the line of a road are, that in crossing valleys or hollows a narrow part of the valley should be chosen, and the deepest part should be crossed at right-angles. The summits of ridges also should be crossed at right-angles; and when roads pass through fields they should, as far as practicable, be formed alongside of the fences, to avoid the subdivision of the fields and consequent loss and inconvenience in working the land.

The most level line between certain points, although it may not be the shortest, is generally preferred. Straight lines are always best, but sometimes debarred by the surface of the ground and other obstacles. To follow the mathematical axiom, that a straight line is the shortest that can be drawn between two points, will not always succeed in making the most commodious roads. A straight and level line is possible only in a country which is perfectly flat, and where no obstacles lie in the way—joint circumstances that rarely happen.

"Cutting through low hills to obtain a level is recommended by some who," Paterson observes, "will argue that where the hill of descent is not very long, it is better, in that case, to cut through it in a straight line and embank over the hollow ground on each side than to wind along the foot of it. This, however, should only be done where the cutting is very little indeed, and an embankment absolutely necessary. Few people, except those who are well acquainted with the subject, are aware of the great expense of cutting and embanking, and the more any one becomes acquainted with road-making, the more, it may be presumed, will he endeavour to avoid those levels on the straight line that are obtained only by cutting and embanking, and will either follow the level on the curved line round the hill, or, where this is impracticable, will ascend the hill, and go over it by various windings, avoiding always abrupt or sudden turnings."

Edgworth was of opinion that a strict adherence to a straight line is of much less consequence than is usually supposed, and that it will be frequently advantageous to deviate from the direct line to avoid inequalities of ground. It is obvious, as he pointed out, that, where the arc described by a road going over a hill is greater than that described by going round it, the circuit is preferable; but it is not so generally known that within certain limits it will be less laborious to go round the hill, though the circuit should be much greater than than that which would be made in crossing the hill.

There are many roads crossing hills which might be made nearly level by deviating a little to the right or to the left. A road is required, say, to connect two points three miles apart, but separated by a hill 100 feet high, and in order to avoid this ascent it is necessary to deviate the line half a mile on either side; yet the road thus curved is only 148 yards, or $\frac{1}{12}$th of a mile, longer than if it had been made to pass over the hill. Whether it is expedient to make the road so much longer to avoid that ascent may soon be ascertained. Telford, as we have seen, estimated the resistance to the load on a level part of a good broken stone road at $\frac{1}{30}$th of the load. A rise of 1 foot in 30 will therefore increase the draught equal to the resistance. In other words, the road may be increased 30 feet in length in order to avoid a rise of 1 foot; or it may be increased 1,000 yards in length in order to avoid an ascent of 100 feet. Where there is much cartage to be done, the greater ease of travelling and the heavier loads drawn on the level would soon do more than compensate for any additional outlay in constructing the longer road.

Bottoming.—In regard to the formation of the road-bed, there are two systems—that of Telford and that of Macadam. The system of Telford is principally a revival of that employed by the old Romans, and consists of laying heavy stones at the bottom of the bed and covering them with a coating of broken stones. Several excellent roads were constructed by him on this principle, the permanence of which are evidence of his engineering wisdom, *e.g.* the Glasgow and Carlisle road, and the road between Holyhead and Shrewsbury. Macadam preferred a yielding to a rigid foundation, and substituted small angular broken stones, laying them directly upon the earth, even upon boggy ground. The angular shape of the stones caused them to bind together somewhat; but the superiority of roads having large stones or concrete (which is preferable, and much employed in the construction of town roads since the manufacture of hydraulic cement became so general) for a foundation is now generally conceded.

"Most failures in road-making have arisen from not having a foundation of depth and dryness sufficient to prevent the road being sunk into the under-stratum of original deposit, and to uphold the upper pressure from sinking the broken materials into the foundation and getting mixed together. In this way both the foundation and the road are lost from being too scanty; the one sinks into the other, and no part is sustained to form the desired object. The foundation must be calculated to sink so far as to find a resting-place on grounds that are not very bearing of pressure, and which remain soft after being drained; the thickness must be sufficient to prevent any extensive mixture with the underlying soil. With the upper bed of broken stones no sinking must take place; the strength and dryness of the foundation must prevent any mixture, except the sinking that will happen from the pressure of the rolling weight. This will not be large when the directions are observed of a dry bottom and thick foundation, and the proper broken materials all duly provided and economically applied."

Covering the base of an unsound road with faggots, branches, furze, or heath is recommended by Edgworth but condemned by Macadam, whose plan was to drain effectually and put no intervening material between the broken stone and the earth.

"Roads," says Macadam, "can never be rendered perfectly secure until the following principles be fully understood, admitted, and acted upon, namely, that it is the native soil which really supports the weight of traffic; that while it is preserved in a dry state it will carry any weight without sinking, and that it does, in fact, carry the road and carriages also; that this native soil must previously be made quite dry, and a covering impervious to rain must be placed over it to preserve it in that dry state; that the thickness of a road should only be regulated by the quantity of material necessary to form such impervious covering, and never by any reference to its *own* power of carrying weight. . . .

Every road is to be made of broken stone, without mixture of earth, clay, chalk, or any other matter that will imbibe water or be affected by frost; nothing is to be laid on the clean stone on pretence of binding. Broken stone will combine by its acute angles into a smooth solid surface that cannot be affected by vicissitudes of weather or displaced by the action of wheels, which will pass over it without a jolt, and consequently without injury."

Macadam was anticipated in his system by Edgworth, who "advocated the breaking of the stones to a small size and their equal distribution over the surface. The latter also recommended that the interstices should be filled up with small gravel or sharp sand—a practice which, though it was condemned by Macadam, is now adopted by the best surveyors." *

Road Surface.—"The smoothness of a road depends on the size of the stones used in forming it, and on their compression either by original rolling or the continued pressure of wheels. The continued smoothness of a road during its wear depends on small stones being used in every part of the stratum; for if the lower part of it, as is often the case in the old style of forming roads, consists of larger stones," the jarring of heavy loads and the action of the weather cause the small surface stones or gravel to sink down between the larger stones, until many

Fig. 1.

of the latter work out on the surface, and the road becomes almost impassable after a few years. Fig. 1 illustrates

* "Roads and Streets." Crosby Lockwood & Son.

the condition of such a road when newly constructed, and Fig. 2 the bad repair into which it has sunk when cut through by heavy traffic.

Fig. 2.

Nothing is so destructive to vehicles, horses, and harness as a road full of ruts and covered with loose stones, or with fixed stones projecting two or three inches above the surface. "If the road is smooth and even, the waggon with its load moves along without jar or detriment; but as soon as a projecting stone is struck the whole load is suddenly arrested, or else it must be lifted to mount the obstruction. This is distinctly represented by Fig. 3, where the curved dotted line shows the upward course which the axle, with its incumbent load, must take in order to pass the stone in the track. A single loose stone, which might be thrown out of the way in two or three seconds, is struck by passing waggons fifty or a hundred times in a day, and many thousand times in a year. The damage which it may do to all the vehicles driven over it may amount, in the aggregate, to many pounds, while it may be removed for less than a farthing."—*Albany Cultivator.*

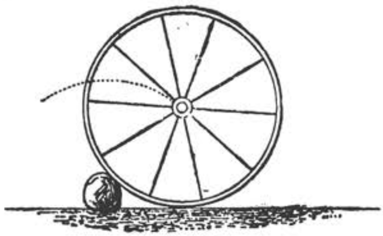


Fig. 3.

Transverse Form.—Opinions differ a good deal as to the best tranverse form of a road. Some think it should be flat, others that it should be higher at the middle than at the sides. There can be no doubt that it should have a certain amount of convexity, but evidently the road will be most suitable for traffic if the convexity is not more than sufficient to make the water that falls on it run off from the middle towards the sides. The convexity may always be reduced to a minimum by giving a slight longitudinal inclination to the road, and a dead level should always be avoided on considerations of drainage. It has also been debated whether the convexity should be given to the foundation or to the surface material only. Telford's system gives the convexity to the "bottoming," by which method a uniform depth of "metalling" is obtained over the whole breadth of the road. If the convexity is given only to the surface material, it must be laid on thicker at the middle than at the sides of the road, and as the traffic usually preponderates in the centre, the more so if the cross-section has a considerable convexity, the action of horses and machines must tend to throw the metal from the centre to the sides, and thus to reduce the road to a level, or to form grooves and ruts. On the best roads the decline from the crown or middle of the road to the side edges is never more than 1 in 50 to 1 in 72, but in narrow country roads it is considerably greater.

Rules of the Road.—In Great Britain there are two well-settled rules, namely, (1) when two vehicles meet, each must bear to the left; (2) when one vehicle overtakes another, the former draws to the left of the way and the other passes by on the off side. In the United States of America, two vehicles meeting bear to the right instead of to the left, but with this modification the rules of the road are the same there as in England. These rules do not apply to equestrians or pedestrians.

CHAPTER III.

CONSTRUCTION OF ROADS.

Foundation.—It is a common practice, in forming a new road, to dig a trench below the surface of the ground adjoining, and in this trench to lay the road-bed or material. "Were the materials of which the road is composed properly selected, prepared, and laid," Macadam remarks, "some of the inconveniences of this system might be avoided; but in the careless way in which the work is generally performed the road is as open as a sieve to receive water, which, penetrating through the whole mass, is received and retained in the trench, whence the road is liable to give way in all changes of weather. A road formed on such principles has never effectually answered the purpose which the road-maker should constantly have in view, namely, to make a secure level flooring, over which vehicles may pass with safety and equal expedition at all seasons of the year. . . . As no artificial foundation can be made so good and so useful as the natural soil in a dry state, it is only necessary to procure and preserve this dry state of so much ground as is intended to be occupied by a road.

"The first operation in making a road should be the reverse of digging a trench. The road should not be sunk below, but rather raised above, the ordinary level of the adjacent ground. Care should at any rate be taken that there should be a sufficient fall to take off the water, either by making drains to lower ground, or, if that be not practicable, from the nature of the country, then the soil upon which the road is proposed to be laid must be raised by addition, so as to be above the level of the water."

Width.—It is recommended that roads be made wide. The first cost of a wide road is, of course, greater than that of a narrow road; but it is an error to suppose that the cost of repairing a road depends entirely upon the extent of its surface, and increases with its width. On a narrow road the traffic is confined very much to one track, and the road is consequently worn more severely than when the traffic is spread over a larger surface. Narrow roads are almost always in bad condition, from the circumstance of every cart or waggon being obliged to go in the same ruts.

The proper width of roads must, however, depend largely on local circumstances. Rules cannot be given to suit every situation nor every farm. The breadth ought to be regulated by the nature and amount of traffic upon the road. Every road should, however, be sufficiently broad to admit of two vehicles passing each other. A width of 13 to 18 feet, prepared for vehicles, will usually suffice for the main road or roads of the farm. For field or cross-way roads the width may be much less, the metalled portion not exceeding 10 feet, while the wings may be left as earth roads. It is a great improvement on all main roads about the farm to have a side-path for travellers on foot, and new roads leading from the farmery to the public highway are now generally so constructed.

Formation.—When a road has to be formed on the natural surface of the ground, the operation consists simply, when the ground is level across, in digging a drain or ditch at each side of the intended road, the earth from which is thrown upon the track so as to raise it a little above the adjoining ground, and slight inequalities which occur in its course are then levelled. If the ground has a sidelong slope, a drain at the upper side of the road only requires to be cut. Macadam, as we have seen, considered this to be all the preparation needed, even on swampy ground, before laying the broken stone covering on a road. Telford believed it necessary to have a foundation of rough pavement (Fig. 4.) below the upper covering, and this he formed of durable stones measuring from 4 to 7 inches, which were set by

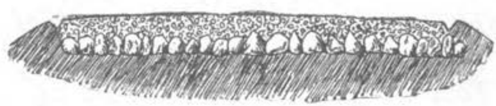


Fig. 4.

hand with the largest sides down, and packed with smaller pieces, so as to form a compact layer of about 7 inches deep at the centre and 4 inches deep at the sides of the road. Above the foundation thus prepared Telford spread a uniform coating of broken stones about 6 inches in depth. Macadam thought 10 inches of metal the greatest thickness required for any road made upon his system, and he often used from 5 to 9 inches as sufficient. In order to carry off the rainfall, the surface slopes from the centre toward the side drains or gutters. This inclination may be 1 in 30 for rough roads, and 1 in 60 for main roads on the farm. A rise of 3 inches at the centre is common for roads 18 feet wide, being 1 in 72.

Road Material.—The road metal should consist of tough and hard stone, such as granite, or some of the varieties of greenstone. Next in order are some sorts of limestone and hard sandstone. Limestone is the principal material in Wiltshire, Somersetshire, Gloucestershire, and Ireland; granite and trap in the north of England and Scotland; slate-stone in North Wales; sandstone pebbles in Shropshire and Staffordshire; flint in Essex, Sussex, and part of Kent; and gravel in Middlesex and Surrey.

The hardest metals, however, are not always the most durable. Toughness is even a more desirable quality in the stone than hardness. Some stones, although very hard, are so free and brittle that they will grind down by the wheels rather easily, and in times of rain will be formed into mud; while, on the other hand, there are stones not so hard that are yet so tough that they waste very slowly, and will last longer than the former on any road whatever.

It has been remarked that in various parts of England where limestone is used the roads are best; and this superiority is ascribed not merely to the hardness of the material, but also to its adhesive or cementing property.

"Flints, reduced to a small size, and mixed with chalk, make an excellent road in dry weather; but, chalk being very absorbent of water, they become slippery and soft in moist weather, and are much affected by frost."

Gravel is the worst material for making roads. Being composed chiefly of hard sand, and smooth, little round stones, it does not so easily bind together, and seldom makes a very firm road, though pit gravel, which is mixed with a larger portion of clay than river gravel, be used. On the other hand, stones that are broken have so many sides that they readily lock into one another; whereas the small round gravel keeps rolling and shifting about by every motion of the wheels. All road metals, therefore, should be of stones so large as to require breaking before they are used.

To insure a firm and compact surface, the stones should be broken into angular pieces about 1½ inches cube, and spread evenly over the road with a shovel and rake in two or three successive layers of 3 or 4 inches deep, each layer being well rolled down or allowed to get partially consolidated by traffic before another is put on.

Macadam's criterion for size was weight; and 6 ounces was the maximum for every part of the stratum. Many of his would-be followers have, however, fallen into the error of supposing that all the stones should approximate to that weight, and recently there has been some danger that this view of the subject would get generalized. This is from not understanding principles.

On being asked by the Road Commissioners to mention the proper dimensions, Macadam stated that none of the stones ought to be larger than would pass through a 2-inch ring, nor exceed 6 ounces in weight. "I hold," he said, "6 ounces to be the maximum size. If you made the road of all 6-ounce stones it would be a rough road; but it is impossible but that the greater part of the stones must be under that size."

"By reference to weight," remarks Stephenson, "the road-maker's operations become more precise; but regard should also be had to the specific gravity of the material, which differs considerably, For example, granite may be taken at 12 cubic feet to the ton, and whinstone (greenstone, basalt, &c.) is often met with of similar weight. Compact limestone and flint are about 14, and quartz sandstone about 15, feet to the ton."

Paterson and other road-engineers have expressed their disapproval of Macadam's 6-ounce test, and think the 2-inch gauge-ring preferable, as there are many stones under 6 ounces that are yet of a very improper shape and size.

Since the introduction of stone-breaking machinery, with cubing and crushing jaws, the road metal can be prepared of any size or fineness; but, on many roads where the machine is used, and more generally where hand-breaking continues to be practised, the stones used are badly broken and unwarrantably large. This is a defect that can and should be promptly remedied on all the public highways. These stone-breakers are made of all sizes, from 7 by 4 to 25 by 16 mouth, and are capable of breaking from 15 to 130 tons of road metal per day, according to the power of the machine.

Gravel for roads ought to be properly cleansed of every particle of clay or earthy substance, and its different sizes separated and arranged by screening. In this gravel the stones are of different sizes and different shapes; and all those that are round, as well as the larger ones, should be broken into angular pieces before being laid on.

Modern Road-making.—The use of binding material on broken stone roads, which was condemned by Macadam and others, is now considered an absolute necessity by the majority of road-makers. The heavy rollers now employed for compressing and settling new materials render the application of sharp sand or gravel necessary to prevent the crushing of the metal. Telford always applied some such binding material to the new metal;

and his practice in this respect is now followed on all roads where road-rolling is understood and practised. The binding of rolled roads is thus so strong that the upper crust may be raised in cakes several feet square, which could never be done without the sand. The sand is only to be applied when about two-thirds of the road metal has been rolled down. "It is essential that this small stuff should not be applied earlier, or it will get to the lower strata, and not only be wasted but injurious. The object is that it should penetrate for two or three inches only, to bind the surface. Provided the upper interstices are filled, the less sand or small gravel used the better; therefore it is applied little by little after each of the three or four last successive passages of the roller, and then only over the places where there are open joints." * Some of the steam-rollers now employed in consolidating new-made roads weigh 30 tons. Rolling is best done in wet weather; otherwise the roads should be watered during this operation.

On farm roads, as a rule, no binding material is used and no rolling is done. The bottom layer, 12 to 18 inches thick, is made of broken bricks, stones, flints, lumps of chalk, or other hard rubbish; and the finishing layer consists of about 6 inches of small broken stones, flints, or gravel.

When a first-class road is to be made the modern practice is as follows: First the ground is levelled and rolled. Then a bottoming of broken stone or other hard material is laid in 12 inches thick, and rolled down to 9 inches. Over this is spread a layer of well-burnt clay or ballast 5 inches thick, and rolled solid to 3 inches. In some districts this is cheaper than broken stone, and the ballast serves to fill up interstices in the bottoming.

* General Sir J. F. Burgoyne, "On Rolling New-made Roads."

Upon the prepared surface of the ballast are laid the small broken stones which form the surface of the road. These are put on in two successive layers, each 3 inches thick, and rolled to 2 inches. With the last layer of small stones, about half an inch of sharp sand is mixed, and the two rolled in together with plenty of water.

Drainage.—If the drainage of the road is to be effected by means of open side-drains or ditches, these should not be made deeper than is necessary, and, if practicable, the fence, if any, should be placed between the side-ditches and the road. It will then be essential that small openings be formed at least every 15 yards to convey the water from the side-tables or gutters through the fence into the ditches. The side-tables, or water-tables, should be made an inch or two lower than the sides of the road.

Open drains, however, occasion an unnecessary waste of ground, besides not being free from danger to passengers and carriages when the road is narrow and there is no fence between it and the ditches. It will, therefore, in the majority of cases, be advisable to form covered drains along the sides of the road, with gratings at proper intervals to let in the surface water. A large-sized pipe should then be laid at the bottom of the drain surrounded with small stones, and upon these smaller stones or gravel to a level with the surface. If the side-drains are constructed in this way, and run immediately underneath the side-table *a*, Fig. 5, no gratings

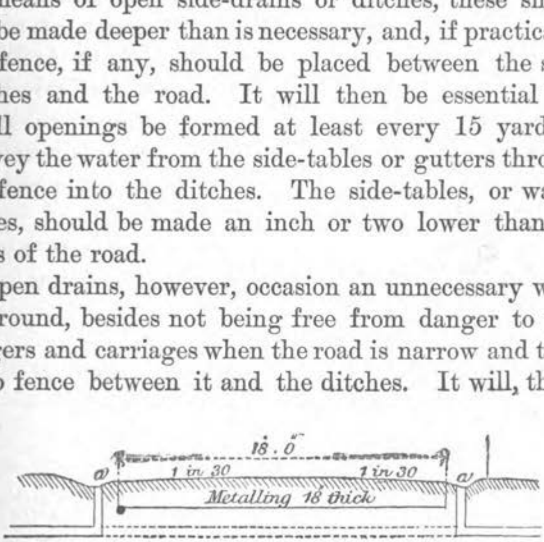


Fig. 5.

will be necessary, as the surface water will then readily find its way into the drains. A cross-drain is also shown by dotted lines in the section of the road, Fig.5, but this will only be needed where depressions occur in the line of road and the water has to be discharged from the road-drains into some natural watercourse. A section of such a cross-drain is shown in Fig. 6.

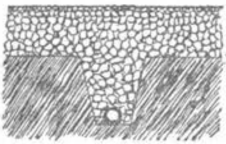


Fig. 6.

Where the ground has a side-long slope, or a road has to be formed on a hill-side, a single drain at the upper side of the road, as in Fig. 7, is all that is necessary, with cross-drains at intervals to discharge the water to the lower side of the road.

A single covered drain down the centre of a roadway is objectionable, because the surface water cannot

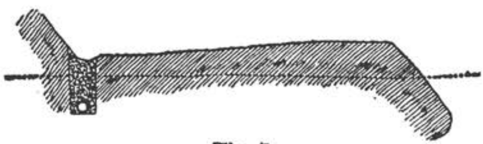


Fig. 7.

reach it without penetrating the road-bed, which is incompatible with the maintenance of a hard and smooth surface.

Fences.—Many of the roads about a farm can be left open or unfenced with perfect safety and convenience. At any rate, it is seldom that a road requires to be fenced on both sides, if we except the main road leading from the public highway. Where road-side fences are necessary they should be of an open kind, such as a wire-fence or a post-and-rail fence. If close fences, such as dykes or hedges, are in existence, they should not be higher than 5 or 6 feet, as they shade the roadway and interfere with its ventilation, and by keeping it always moist make the draught excessive. Trees are worse than hedges when they overhang a road, because they not only deprive the road of the benefit of air and sun, but they further injure it by the dripping of rain from their leaves, as a consequence of which the road is kept in a wet state long after it would otherwise have been dry.

Cost.—The expense of road-making will be found to vary, even in the same district, as, in addition to the cost of labour and the nature of the ground, very much depends on the facility for obtaining the necessary materials. In one case we have converted an old lane, which was previously a perfect quagmire, into a good hard road at a total cost of 3*s.* 8*d.* per lineal yard. The stone in this instance had to be dug out of the ground, and was laid on 12 inches thick and 13 feet wide. The above price includes draining the road, throwing up the surface, digging, carting, and breaking the stone, and laying it on. Mr. Dawson states that he has made many gravel roads, 12 to 18 inches thick, at a cost of from 2*s.* 6*d.* to 3*s.* 6*d.* per square yard. Country roads formed of broken stone commonly cost from 1*s.* 2*d.* to 1*s.* 6*d.* per square yard.

Mr. Denton states the cost of farm roads made in various parts of England at from £3 to £6 10*s.* per chain, and gives the following examples: (1.) A road made in the New Red Sandstone district, of which the bottom stratum, 6 inches thick, was formed of a rough paving of local stone, covered with 4 inches of broken limestone, cost from £4 12*s.* 6*d.* to £6 17*s.* 6*d.* per chain. (2.) A road in a fen district, in which perforated bricks, laid flat on a convex base, and covered with burnt ballast, formed the bottom stratum, with a surface-covering of screened gravel, was estimated to cost £5 17*s.* 6*d.* per chain. (3.) A road in the Lias and Oxford Clay district, with the bottom stratum of burnt ballast, and the top of screened gravel, cost from £4 10*s.* to £5 10*s.* per chain. (4.) A road in the London Clay district, the bottom stratum of chalk, and the surface-covering of screened gravel, cost from £3 10*s.* 6*d.* to £4 15*s.* per chain. Reducing the chain to yards, we find that Mr. Denton's roads cost from 2*s.* 7½*d.* to 5*s.* 11⅛*d.* per lineal yard. Their width is not stated, but it may be assumed that they are about the average width of farm roads.

Repairs.—The repair of a road consists in keeping it smooth and clean, and should commence immediately after it is made. Hollows must be filled up, to prevent water standing on the road and the formation of ruts; and loose stones and mud must be assiduously taken off. After a time, a thorough repair or surface renewal by a coating of broken stone over the whole of the road may be required. The stones gathered off the fields will afford a greater or less supply of materials, and must be laid in convenient places and prepared by breaking ready to be put on when needed.

In repairing a broken stone road, the surface should be slightly loosened with a pick, and a layer of new metal spread evenly over it, and well consolidated by heavy rolling.

For the repair of an old road, Macadam directs that no addition of material is to be made, unless in any part it be found that there is not a quantity of clean stone equal to 10 inches in thickness. The stone already on the road is to be loosened up and broken, so that no piece shall exceed 6 ounces in weight. The stones, when loosened in the road, are to be gathered off by means of a strong heavy rake, with teeth $2\frac{1}{2}$ inches in length, to the side of the road, and there broken, and on no account are stones to be broken on the road. When the great stones have been removed, and none left in the road exceeding 6 ounces, the road is to be put in shape, and a rake employed to smooth the surface, which will at the same time bring to the surface the remaining stones, and will allow the dirt to go down. When the road is so prepared, the stone that has been broken at the side of the road is then to be carefully spread on it; not in shovelfuls, but scattered over the surface, one shovelful following another and spreading over a considerable space. The tools to be used are strong picks, but short from the handle to the point, for lifting the road; small hammers of about one pound weight in the head, the face the size of a shilling, well steeled, with a short handle; rakes with iron teeth about two inches and a half in length, very strong, for raking out the large stones where the road is broken up, and for keeping the road smooth after being relaid and while it is consolidating; very light broad-mouthed shovels, to spread the broken stone and to form the road.

Telford's directions for repairing roads differ little from his instructions for forming roads. Where a road has no solid and dry foundation, he breaks it up, lays bare the soil, drains it, and bottoms with stones set by hand with the broadest end down, in the form of a neat pavement; over this foundation he lays on 6 inches of broken stones. Where a road has some foundation, but an imperfect one, or is hollow in the middle, all the large stones appearing on the surface of it must be raised and broken; and the road so treated is then to be covered with a coating of broken stones, sufficient to give it a proper shape and to make it solid and hard. Where a road already has a good foundation and also a good shape, no materials should be laid upon it but for the purpose of filling ruts and hollow places in thin layers as soon as they appear; stones broken small, being angular, will fasten together. In this way a road, when once well made, may be preserved in constant repair at a small expense.

The best seasons for repairing roads are generally considered to be autumn and spring, when the weather is moist rather than otherwise. Although it is proper, Paterson remarks, at all times of the year to put on a little metal whenever any hole makes its appearance, yet in the drought of summer this will seldom be necessary. In summer the roads are less liable to cut; but if, at some places, a little fresh metal may be necessary, no more should be put on than is barely sufficient to bring these holes to the level of the rest of the road. Metal put on in the drought of summer does not soon bind together. Until such time as there is rain sufficient to cause them to bind, the stones will keep shifting and rolling about, and make a very unpleasant road to travel on. The most proper times of the year to put on any quantity of road metal are about the months of October and April, as the stones always bind best when the road is neither too wet nor too dry. When they are put on about the month of October they become firm before winter, and, with a little constant attention, the road will be easily kept in good order till the spring; and if it has been the case that the road has not been sufficiently attended to during the winter, and that it has got into a bad state towards the spring, by putting on fresh metal about the month of April, sufficient to bring it into smooth surface order, it will be very easily kept in this good state throughout the summer.

Unmetalled Roads.—The central roads of the farm require to be hard roads. In many positions, however, where field roads are necessary to afford facility for transporting produce and manure, and for keeping the ploughing-engines off the cultivated land, broken stone roads would be too expensive to construct, as they would be seldom used, and in such places burnt clay roads or even grass roads will be found to answer every purpose, especially where traffic upon them can be avoided in wet weather. On Mr. Prout's farm, in addition to hard gravel roads across the middle of the farm, communicating with the homesteads, there are two miles of grass roads, which were formed by simply ploughing and rolling, and then partially coating the top with small stones picked off the fields. These green headland roads are 10 feet wide, and from them the engines can cultivate every portion of every field without travelling on the land. Such roads cost very little to construct, and add immensely to the facility of working the land. These grass roads are very common in plantations, where they are found a great convenience on many occasions, such as in thinning and clearing out produce, in covert-beating, &c. In plantations, however, they generally require to have side-drains or open ditches, which are never necessary with field roads, and are the more expensive. Still, with side-drains 3 feet wide at the top and 14 inches at the bottom, and 2 feet deep, grass roads 18 feet wide can be formed at an average cost of 18*s.* per 100 yards. Burnt clay roads are much cheaper than broken stone roads, but will cost from 50*s.* to 70*s.* per 100 yards when laid a foot deep and 12 to

15 feet wide. They soon cut through with heavy traffic in wet weather; but where the traffic is light, and even with heavy traffic in dry weather, they are wonderfully durable. For carriage-drives the burnt clay or ballast makes a splendid road, as it is always smooth, is comparatively noiseless, and can be kept in repair without much trouble or expense. In the fen and clay land districts, where stones for road-making are often unobtainable, well-made ballast roads answer effectually for the heaviest traffic on the farm.

CHAPTER IV.

PAVEMENTS.

PAVED roads, though common enough in towns, would be out of place on the farm; but on most farms there is some extent of pavement in or around the courtyards or stable-yards, where much trampling goes on, and common roads cannot easily be kept dry and clean. For such purposes pavements are very suitable in all country places.

Pavements as now laid down are of three kinds—stone, wood, and asphalte.

Stone Pavements.—The best stone pavement is one of rectangular blocks set in contact on their longest edges across the road, and resting on a foundation of concrete, or rubble-stone filled in with concrete. The blocks should not be more than 3½ or 4 inches broad, measured along the road; 9 to 12 inches long, measured across the road; and 8 to 10 inches in vertical depth. The Belgian pavement, in which the blocks more nearly resemble a cube, varying from 5 to 7 inches on each side, is but little inferior to the above if the foundation be equally good. For paving farm-yards, however, smaller stones are often preferred, and they are usually set in sand and well rammed. When the blocks, whether rectangular or cubical, rest on a sand foundation, they should all be equal in bed-area to prevent unequal settlement. In some instances the paving-stones have been set on concrete, with the joints grouted with lime and sand, to insure a great degree of stability. Telford recommended a bottoming or foundation of broken stones, 12 inches deep; and he used paving-stones 4 to 6 inches in width, 7 to 13 inches in length, and 7 to 10 inches deep. The 6-inch wide paving-stones have been generally abandoned in favour of narrow ones, 3 or 4 inches in width.

Stones in a common pavement are usually somewhat oval, and they are laid either in parallel rows in the road (Fig. 8, *c d*), or alternately (*a b*) as bricks are laid in a wall. "On the first sort of pavement," Edgworth observes, "wheels slip from the round tops of the stones into the joints between, and some wear away the edges of the stones and their own iron tire. By degrees channels are thus formed between some of the stones, and in time the pavement is ruined." On the second sort of pavement (*a b*), where the stones are placed alternately, the wheels are prevented from forming grooves, and all the more so when the stones are small and are compactly laid.

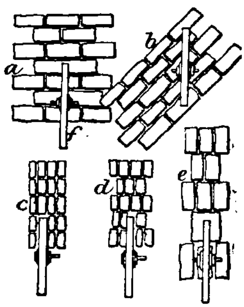


Fig. 8.

Wood Pavements.—Wood is now extensively employed for paving purposes, and for courtyards is much superior to stone, being less in first cost and more noiseless. The wooden pavements are formed of blocks of fir-wood, 3 to 4 inches broad, 8 to 14 inches long, and 6 to 8 inches deep. The blocks are set on their longest edges close together across the road, with an open joint about ¾ inch wide between the course. The blocks should rest on a well-constructed bed of sand or a layer of boards. Wood blocks would soon be destroyed by crushing if set upon a rigid, inelastic foundation. The wood should be creosoted to prevent early decay; and the resistance of the wood is most effective when the fibres are in a vertical position, and least effective when they are horizontal. The open joints are filled with a mixture of prepared coal-tar and sand or gravel, and a small quantity of sharp sand is strewed over the tar. In some recently-formed pavements the blocks of wood are set upon a carpet of tarred felt, the latter laid upon a prepared bed of sand, and a strip of tarred felt is placed, edgewise, between the courses.

Asphalte Pavements.—Asphalte is largely employed for paving streets in London, its advantages being that it produces no dust and therefore no mud, is comparatively noiseless, is impermeable to water, is smooth, and consequently reduces the wear and tear upon animals and vehicles to a minimum. A good asphalte pavement requires a solid foundation, preferably either of concrete or rubble-stone filled in with concrete. The asphalte covering may be natural asphalte rock derived from the Jurassic region on the confines of Switzerland, or it may be composed of asphaltic cement suitably prepared by refining natural bitumen, to which is added a calcareous powder to take the place of the amorphous carbonate of lime contained in the natural asphalte rock. It is usually applied upon the foundation in a continuous sheet of 2 or 3 inches thick, although it may be used in the form of a rectangular block prepared under heavy pressure. A distinction must be made between pavements of genuine asphalte, properly prepared, and all those patented imitations of or substitutes for it composed of wood-tar, coal-tar, pitch, resin, &c., mixed with either sand, gravel, ashes, lime, &c., or with two or more or all of them. These latter are unfit to support heavy traffic.

Comparative Merits.—The comparative merits of stone, wood, and asphalte pavements are as follows:—(1.) In point of durability, stone is first, asphalte second, and wood third. (2.) As regards first cost, wood stands first, asphalte second, and stone third. (3.) In respect to maintenance and repairs, the order of merit is first stone, second asphalte, and third wood.

CHAPTER V

FOOTPATHS.

GOOD substantial footwalks, leading from the farmhouse to the steading, to the garden, and to the high-road, are comforts that ought to be enjoyed by every farmer and his family in their daily outgoings and incomings. Capital walks are made of large flat stones or flagstones, but these are not everywhere obtainable, though they answer the purpose better than any other kind of material in clay districts. The most common material used for walks is small gravel, and next to that, perhaps, burnt clay; but for garden walks asphalte is now commonly employed.

Gravel Walks.—Whether the gravel is dug from a pit or is obtained from the beach or river bed, it should be well screened before hauling, and thoroughly freed from earth and dirt. The larger-sized gravel should at the same time be rejected. The rotary screen is a useful machine for preparing gravel for walks and road-making, as well as for screening ashes and artificial manures. It can be made to separate three different sizes—the very fine earthy matter, the large stones, and the fine gravel, the latter only being used for the walks.

The footpath should be 3 feet in width and 18 inches in depth, and before being excavated it should be lined out on both sides, and edged by means of a garden spade.

A section of a walk is shown in Fig. 9. The bottom is filled with broken stone or any hard rubbish, and 8 or 10 inches of the top are covered with fine gravel. To prevent earth mixing with the gravel, which will soon cause grass and weeds to grow up through the walk, the edges should be cut with a sharp spade as often as is necessary to remove any soil or turf that has encroached upon the gravel. When grass or weeds do appear on the path, the surface should not be loosened in the endeavour to eradicate them. They may be readily extirpated without injury to the walk by an application of common salt. On springy ground a

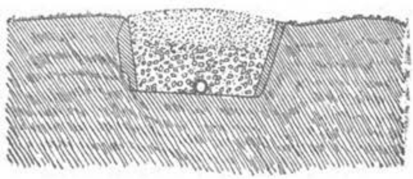


Fig. 9.

pipe-drain should be placed in the bottom of the walk, with proper outlets at the required points. The walks require frequent heavy rolling to maintain them in good condition.

Asphalte Walks.—The best walks of this kind are constructed of natural asphalte, applied in the liquid form, with a large proportion of sand. Artificial asphalte, which is obtained by mixing heated limestone and gas-tar, though possessing some of the properties of liquid asphalte, is a very inferior material, as it is brittle, and passes from the dry to the liquid state, and conversely, according to the weather. There are different mixtures of artificial asphalte in common use for walks, and these are often variously applied. One uses 3 parts coal-ashes and 2 parts of gas-lime from the gas-works, thoroughly mixed together, and then made into a mortar with gas-tar. Another uses 3 parts of gas-tar and one of common pitch, melted together, and then mixed with sand as for common mortar. The mixture is laid on the surface of the walk 2 or 3 inches thick, a suitable foundation and

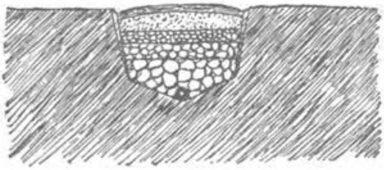


Fig. 10.

bottoming of broken stones having first been prepared. If a drain is needed, a pipe-tile is placed in the bottom of the broken stones; and by making the broken stones communicate with the surface at the edges of the walk, as shown in Fig. 10, the rain-water is readily admitted to the drain.

CHAPTER VI.

FARM TRAMWAYS AND PORTABLE RAILWAYS.

TRAMWAYS are now used to a considerable extent in and about farm steadings for such purposes as carrying turnips and fodder to the cattle, and for carrying out manure from the feeding-boxes and stalls. Fig. 11

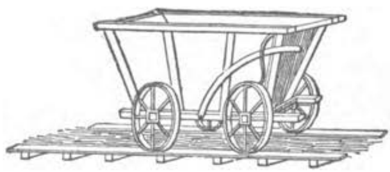


Fig. 11.

represents a tramway waggon employed in this kind of work.

The use of tramways and portable railways for farm purposes admits, however, of a more extended application. In an experiment exhibited by Mr. Wilkes before the Society of Arts, a moderate-sized horse drew, upon a railway declining 1 foot in 100, 32 tons easily, and 43 tons without much difficulty, dragging it down hill, and 7 tons going up hill, independent of the weight of the carriages. It was concluded from this experiment that upon a level tramway a horse could draw with ease 20 tons. The possibilities which tramways offer for economizing horse labour on the farm will readily suggest their application to different purposes in many situations.

Where permanent tramways are not a necessity, and there is much irregular transit of produce or goods of any kind, Greig's Portable Railway may be used with great advantage. Its portability and easy adaptation to every description of traffic renders it absolutely indispensable in many situations.

The system may be advantageously used for clearing hay in irrigated meadows, thus preventing the destructive action of the wheels of heavily loaded carts. It is also extensively adopted by planters in the West Indies, Brazil, Australia, and other parts.

One of the most important items in the management of large agricultural undertakings is the cost and facility of transport. During harvest time, especially when dealing with heavy crops—such as beetroot, sugar-cane, &c., and for many other agricultural operations—it becomes more and more essential to secure ready means for removing produce and material in the most expeditious way and at the cheapest possible rate, and to save manual and animal labour as much as possible.

This is especially the case in connection with steam cultivation, which has provided the farmer with the means of dispensing with animal labour as regards the heaviest work hitherto performed by horses or cattle. If now, by some other mechanical means, the demand on this kind of labour for the purposes of transport can be reduced materially, the two most important and expensive operations of agricultural management will be freed from the necessity of animal labour.

Greig's railway is made in sections 15 feet long, each having one double and three or four single corrugated steel sleepers. The plant is so light that a section can be easily lifted and moved by one man, and any labourer can relay it.

The principle upon which Greig's system is based is that of distributing loads upon a large number of wheels, and avoiding the use of heavy and cumbersome plant. The material to be removed is in most cases divided into loads weighing from 10 to 15 cwt., which are carried on small waggons, each having two axles.

If the material to be carried is of such a nature that it cannot be divided, or is too bulky for the ordinary waggons, small wheel bogies are employed, forming bogie waggons with bodies constructed in various forms convenient for the purposes for which they are intended.

By these arrangements and the many modifications which have been introduced, almost any description of load may be easily transported, and the waggons will pass freely around curves of small radii, even when loaded with material of great length.

The great superiority of this system of railway arises from the fact that the roads are rigidly secured to metallic sleepers, the jointing of the rail being also effected by means of steel chairs (which are rivetted to the sleepers) and clutch bolts of peculiar form, thus avoiding the drilling or puncturing of the rails and the use of loose fish-plates and bolts.

This arrangement ensures the line being accurate in gauge in all points without any adjustment, and this accuracy is maintained as long as the line remains in use.

The line may also be laid down and taken up very expeditiously without the exercise of skilled workmen.

It is impossible to enumerate the many purposes and trades to which this system of portable railway may be advantageously applied; but it is working successfully in cotton and sugar plantations and in other agricultural undertakings, farming and land reclamations, gathering beetroots, turnips, and other heavy crops.

Wherever there is material of any kind to be removed, this railway system will prove a valuable assistant in the work, and wherever it is adopted will effect a large saving in manual labour and horseflesh.

The railway is perfectly portable, since it can be laid down and taken up again without the help of any tool whatever. To give an idea of the facility of these operations where frequent removals are necessary, that is to say in clearing land of beetroot or sugar, &c., six men take up 250 yards of railway and relay them 50 yards farther on in twenty minutes, the line being moved in lengths of about 25 yards.

In order to enable our readers to form some idea of the economy of this plant, we give an extract from the letter of a sugar-planter in Cuba who is using it: "They began to put the line into the cane-patch on the 26th inst. about 2 P.M., and by 4 P.M. they had about 350 yards laid. By 7 P.M. they had drawn 64 waggons and one platform-waggon of cane to the mill with 6 oxen and 3 men. The waggon-loads weighed nett 8 cwt. 2 qrs. 2 lbs. each, and the platform-waggon carried a nett weight of 26 cwt. 2 qrs. 24 lbs. It would have taken 22 carts and 88 oxen and 22 men to have drawn the same total of cane by ordinary ox-cart loads. The labour of loading the waggons is very much less fatiguing than that of loading the carts. The waggons, both platform and ordinary carrier, run easily on the well-laid fixed line, but the platform-waggons run more easily than the others.

Our illustration, Fig. 12, shows the portable railway in use on a sugar estate. Turntables are laid down at each crossing, and the empty waggons are pushed along by hand to the spot of loading, while the loaded waggons are drawn off the field by animal or by steam-power.

Cost.—The cost of the portable railway for animal-power lines varies from £307 to £342 per mile, or upwards, according to the gauge of lines and weight of rails. Shorter lengths can be had at from 3*s.* 6*d.* to 3*s.* 11*d.* per yard. The fittings and plant are extra.

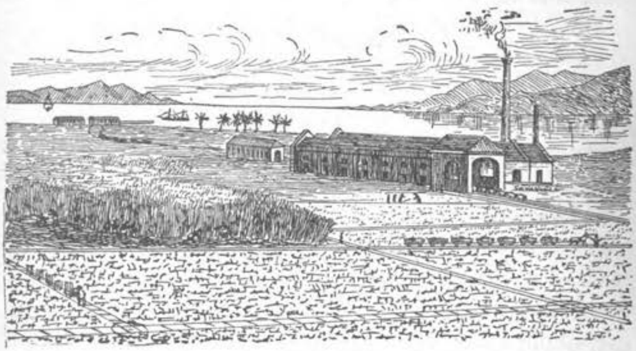


Fig. 12.

For locomotive-power lines, the cost varies from £468 to £518 per mile and upwards, with plant and fittings extra, and shorter lengths at from 5*s.* 4*d.* to 5*s.* 11*d.* per yard.

Portable Railways used in Steam Ploughing.—Instead of forming headland roads for keeping the heavy ploughing-engines off the cultivated land, temporary rails may be laid down for the engines to travel upon, as illustrated in Fig. 13. Mr. Osborn applied this system as early as 1846 to steam-ploughing in Demerara, where there are no roads on which the engines could travel, but the open drains presented an insurmountable

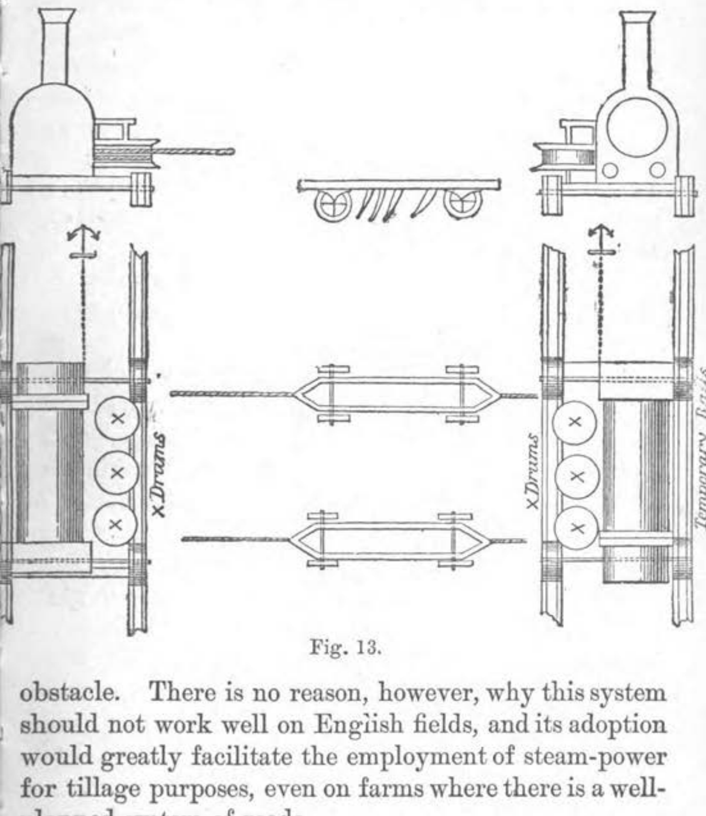


Fig. 13.

obstacle. There is no reason, however, why this system should not work well on English fields, and its adoption would greatly facilitate the employment of steam-power for tillage purposes, even on farms where there is a well-planned system of roads.

gation canals. On the Demerara sugar plantations, where the whole of the heavy field transport is carried on by means of the navigation canals which surround every field, as shown in Fig. 14, there is a loss of some-like one-tenth of the whole land enclosed by these canals alone, and a greater loss—equal to one-seventh of the entire field—by the open drains which intervene.

Great, then, as the facilities are which a system of canals may offer in some respects, it is obvious that there is a limit to their multiplication where land is of much value. In Demerara the open drains interfere greatly with the economical working of the field canals, and add immensely to the difficulty of bringing a sugar-cane crop off the field after it is cut.

The cost of cane-cutting is calculated at 4 dols. per hogshead of sugar, and as the average yield is about two hogsheads per acre, the cost of cutting, which includes carrying out the cane to the canal sides, may be taken at 8 dols.

At present, however, owing to these open drains, the reaper has not only to cut the canes, but carry them to the parapet, where they are thrown down, to be lifted a second time by other hands engaged in loading the punts. Now there are from six to nine hundred bundles or head-loads of cane to an acre, and as the average distance walked for and with each bundle is 70 yards, it amounts to 30 miles travel in clearing an acre. Not ordinary travel either, for half of the way the labourer has to carry a load of 75 lbs., and to cross as many as 1,275 drains.

To be sure, there is Greig's system of clearing cane-fields, in which two ordinary ploughing-engines are placed on the opposite roads, their ropes being connected by a shackle, to which a spare chain is fixed. The waggons are attached to this chain and hauled over the field from one engine to the other, being steered along the uncut edge of the sugar-cane and loaded at the same time. This system applies particularly to very large estates, and where constant employment is afforded for the machinery. Where the employment is not so regular, a cheaper system may be inaugurated. It is just possible that a wire-rope carrier might be employed with more advantage in cleaning the land and delivering the canes to the waggons on the central road.

On the present system, loading and transporting canes is reckoned to cost 1 dol. per hogshead, but the actual cost is a great deal more. In order to show this with some accuracy, we may here take into account the different items of expense in this consideration. To load and pick up the canes costs not less than 12 cents per punt, and as it takes 6 punts or so to the hogshead of sugar, this amounts to 1 dol. 44 cents per acre. The lowest possible number of punts in use on a large estate will be one for every 25 acres of crop. Now the first cost of a wooden punt is at least 80 dols., interest on which at 5 per cent. is 16 cents per acre; and as the wear and tear is equal to about 12½ per cent., the use of the punts may be said to cost 56 cents per acre. There are also the punt mules to be considered. The annual expense of a mule is as follows :—

Feed and attendance	40 dols.
Harness	3 ,,
Interest on capital	5 ,,
Risk	10 ,,
	58

If, then, there are two mules for every 100 acres in canes, the expense will be 1 dol. 16 cents per acre. A driver at 3 cents per punt is 36 cents per acre more. And,

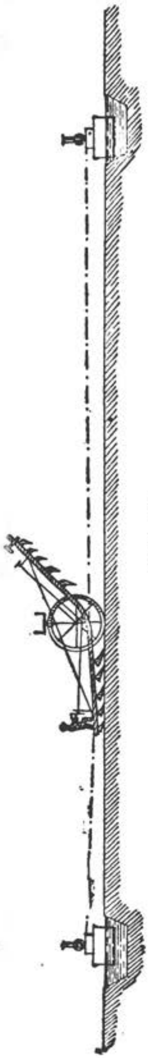


Fig. 15.

lastly, there are navigation trenches to be kept in repair. It is rather below the mark to say that there are 9 rods of trench per acre to be cleaned or weeded once a year and dug bi-annually—say weeding at 2 cents, and digging at 16 cents, per rod—in all amounting to 90 cents per acre. Transporting, therefore, must be taken at 4 dols. 42 cents per acre.

We make no doubt that this could be done at considerably less cost by a system of roads, and still more economically by means of the portable railway, if a system of covered drains prepared the way; but of course where canals are already constructed, it will in most cases be advisable to adhere to them, notwithstanding the loss of ground they occasion, until such time at least as land becomes so valuable that no part of it can be permanently left out of cultivation. In laying out new estates, however, there is no such consideration to prevent the immediate adoption of the transport system, which is the most economical both in its working and in its contingent effects.

Ploughing with Engines in Punts.—This plan of working was originated by McRae, on the Demerara fields, in 1839; but the machinery then available was cumbersome, and, instead of two engines being employed, there was one engine in one punt, and an anchor in the punt on the opposite canal. Fowler's direct double-engine system of steam cultivation is now practised on several estates in the colony, with both engines in punts, as shown in Fig. 15. The fields so cultivated have been previously tile-drained, and had the old open drains filled up. Cultivating from canal to canal entails working across the shortest length of the field, which is only from 165 to 178 yards, whereas the length from the middle walk to the side-line dam is never less than 550 yards. The former lengths are too short for economical working, from the number of turnings involved, and the only remedy would be to double the distance between the engines, by filling up every alternate canal; but this would necessitate the adoption of some other method of clearing the fields than that of the labourers carrying out the sugar-canes by back-loads, as is now done, for the distance between the punt-trenches is already too great for that.

CHAPTER VIII.

ENCLOSURES.

In the pastoral state of society men wandered about in communities and fixed their abode only where they could obtain pasturage for their live-stock, their sole occupation that of tending their flocks and herds. Attached to a convenient spot they probably made an enclosure, suited to the number of their live-stock, near their own dwellings, to confine them during the night. This enclosure would serve the double purpose of relieving the night watches of the shepherds and of protecting the live-stock against the attacks of wild and ferocious animals.

A similar practice followed the first attempts at cultivation. The cultivated land was near the dwellings, and was surrounded by a single fence; and hence the origin of the ancient mode of subdividing land into *outfield* and *infield*, a practice which was continued till later times and more enlightened ideas swept the distinction away, and the ancient *ring-fence*, which only surrounded the cultivated land, was removed to the boundary of the farm. In flat countries subject to inundation, canals and ditches, for the purpose of extending the benefits of irrigation, were formed instead of fences.

There is no doubt that the only method of enclosing land practised by the Romans was that of the ring-fence around the cultivated ground; and it is probable that this was the only mode known to the ancient Greeks and other nations.

Before the extensive use of fences, landed property was marked out by *stones* or *posts*, set up so as to ascertain the division of family estates. Such *land-marks* constituted the customary method of distinguishing landed property among the Israelites, and to remove them was a crime similar to altering, destroying, or concealing the title-deeds of estates at this day. The law of Moses denounces curses on those who remove their neighbours' landmarks. Even among the heathen the landmark was sacred—so sacred that they made a deity of it. The owners of both fields brought each his garland and libation to the honour of this god. They sung its praises, put on its top a chaplet of flowers, poured out the libation before it, and the inhabitants of the country held a festival in its honour. It was, in short, celebrated as the preserver of the bounds and territorial rights of tribes, cities, and whole kingdoms, and without its testimony and evidence every field would have been a subject of litigation.

Some such ancient ceremonials, it is curious to observe, are practised amongst ourselves at the present day. At Hawick, the marches of the landed property of the town are distinctly pointed out every year, in the month of June, by the magistrates, cornet, and a large number of the inhabitants, all on horseback, which procession, concluded by a civic festival, is called the "Common-riding." An old song, annually sung by the inhabitants on the occasion, dwells with spirit on "Our marches rode, our landmarks planted"—a formal demonstration of their legal rights which was doubtless really necessary in ancient times, when written documents were in constant danger of being destroyed. At Selkirk, another royal burgh, as the burgesses in procession annually ride the marches, the town miller comes forth with cakes and other offerings, as, it appears from Juvenal, was done amongst the Romans of old, whose offerings of cakes, first-fruits, and flowers were, however, made to the sacred *termini*, or landmarks, and not to the citizens who were patrolling the bounds of their "known inheritance."

> "Those bounds, which with procession and with prayer
> And offered cakes, were made their annual care."

The ancient mode of enclosing land is still practised by many of the modern nations of Europe. In France property is so much sub-divided, by the extinction of the law of primogeniture, that no field enclosures are to be observed in that country—a few march-stones, a row of trees, or particular single trees here and there, marking the boundaries of estates. Nearly 6,000,000 transfers of property take place annually in France, and they are made with such uncertainty as to boundaries as to lead to numerous disputes, no less than 22,000 out of some 45,000 civil causes tried yearly relating to succession of property. Throughout Germany, Italy, Spain, and Switzerland, enclosures are only found near farmhouses and villages, the bulk of the corn being raised on extensive unenclosed grounds. In Holland and Belgium, on the other hand, the land is so much enclosed that the fields appear half choked with hedgerow-trees and hedges. In some parts of the South of England, also, much valuable ground is occupied by over-numerous and often sadly overgrown and neglected hedges; while in Ireland land is much subdivided by turf dykes.

The size of enclosures must be regulated by the system of cultivation pursued, and by the extent of land undergoing the rotation; but these requirements should be made to harmonize as much as possible with the local considerations affecting the utility of fences, particularly the conditions of climate and shelter. Shelter is required both against heat and cold, and its attainment should be studied in the formation of enclosures. Trees form the best protection, and where they are obtainable no other shelter is required, and the advantages in such situations will always preponderate in favour of large enclosures and open fences. In elevated districts, exposed to the force of the wind and destitute of trees, a compact fence is all the means of shelter at command, and therefore, within a certain limit, their increase will prove beneficial. But in low-lying ground, well sheltered by trees or by the natural configuration of the surrounding country, there is practically no other object requiring the formation of a fence than its primary use of providing an efficient enclosure for grazing purposes. In such districts the utilisation of fences for shelter should be carefully guarded against, both because they are unnecessary for such a purpose and because their effects are hurtful alike to the climate and to the surrounding soil, and, consequently, injurious to the crops. This is especially the case when the enclosures are of small extent.

The broad hedgerows which are to be seen in many parts of England, composed of a belt of trees flanked on each side by a hedge, and having a dense growth of underwood, are positively injurious to the land. No doubt the object of cultivating these hedgerows (if there is any definite purpose in view at all) is the double one of providing for the growth of firewood and of securing shelter. But, if the intention is good, the results of making a plantation out of a fence are neither satisfactory nor profitable. They prevent the soil from drying quickly if it is naturally damp, and, by the stagnation of the air which they induce by obstructing the free flow of the atmospheric currents, they poison all the surrounding grass and crops. They are also complete nurseries for weeds, and afford shelter for insects, vermin, and such birds as are destructive to crops, from which cause the headlands of the fields are generally quite lost to the farmers; and there is the additional loss of the ground occupied by the superfluous width of the hedgerows themselves.

A fence should always be as narrow as possible, consistent with due fitness for its purpose. The space required will, of course, vary according to the different kinds of fences used; but in a hedge, for example, which occupies more space than any other system of fencing, there is seldom any reason or necessity why the width should exceed 3 feet. The economy of guarding against excess of width in fences is very apparent by a simple calculation. If we allow a hedge to occupy a width of 2 feet, and cultivate the ground on each side to the distance of 3 feet from the centre of the fence—which allowances are certainly very far short of the real practice throughout the country—we should find that on a farm of 250 acres, laid out in 25 fields of 10 acres each, there is an area of more than 4½ acres, or a 55th part of the whole, entirely lost to cultivation through the use of fences.

It is generally admitted that fields which are surrounded by hedges are more fertile than those which are unenclosed; but this is not universally true without limitations. In dry situations and on light sandy soils they are undoubtedly of great benefit from their effects in preventing the escape of moisture, and, therefore, in such places their value will, in some measure, increase in proportion with their number. But, on the other hand, these same effects must be injurious to a soil which is naturally damp and moist, if the hedges abound in number.

There are a great many different kinds of fences now in use, but all those of any importance will be noticed separately in the following chapters.

The great expense of erecting new fences and of repairing old ones is a good reason for having as few of them as possible.

A common light wire fence will cost at least 8*d.* per lineal yard, or £58 13*s.* 4*d.* per mile. To enclose a farm of 640 acres (1 square mile) in a ring-fence, will therefore entail 4 miles of fencing, at a total cost of £233 13*s.* 4*d.*; or, assuming that adjoining occupiers share half the cost, £116 16*s.* 8*d.* If this farm is subdivided into fields of 20 acres, there will be 32 fields, entailing 10 miles of interior fencing—making a total of 12 miles, and involving an outlay of £704, or £1 2*s.* per acre. The above estimate is certainly not overdrawn. The cost of almost every other description of fence would be greater, and there are few farms where the fields average 20 acres. It must also be remembered that over and above the first cost there is the expense of maintenance and repairs, not to mention the loss of land occupied by the fences. If we take 12 per cent. per annum on the capital sunk in fences to cover interest, maintenance, and repairs, it amounts to 2*s.* 8½*d.* per acre; and if the loss of land is 2 per cent. on 640 acres, there are 13⅓ acres, which, at an annual rent of 20*s.* per acre, adds another 4½*d.* per acre over the farm, making the total annual cost of fences 3*s*. 1*d*. per acre.

The cost of keeping a large farm well fenced into many fields is very considerable; but, when viewed collectively, the amount of capital employed in the construction and repair of fences in this and many other countries is simply fabulous.

There are 45,000,000 acres of enclosed land in the United Kingdom; so that, on the foregoing estimate, the capital sunk in fences must be nearly £50,000,000, and their annual maintenance and repair must cost at least £6,750,000.

The common fences which divide the fields from the highways and separate them from each other, are, it is seen, one of the greatest investments in this country, albeit an unproductive one.

Some systems of farming do not require that inside fences should be kept up; but there is always an advantage in having the farm laid out in fields, even when there is no necessity of erecting fences on the dividing lines. The crops themselves show the boundary of each lot. Moreover, the measurement of every field should be known, for convenience in estimating the quantities of seed and of manure to be used, of tillage and labour to be expended, and of produce to be reaped.

CHAPTER IX.

HEDGES.

Quickset Hedges.—There are a great variety of plants used in the cultivation of hedges, but the plant which is best adapted to the purpose is whitethorn or hawthorn (*Cratægus oxyacantha*), also called quickset. It is almost the only one which produces a good fence of compact growth, and of all others its use is attended with the fewest disadvantages. It can be managed so as to form a compact and equal fence, and yet occupy very little space. Its roots do not throw out new ramifications into the surrounding soil; it stands the severest winter without injury, and, on account of its thorns, it is avoided by all animals, and does not harbour birds and insects, unless it is allowed to spread out its branches to an unnecessary extent.

Season of Planting.—Thorns are planted in a hedge from autumn, when the leaves drop off, till spring, when the buds begin to swell, unless in frosts and heavy rains. When planted about October the plants are said to be more healthy than if put in at any other time, and there is undoubtedly this to be said in favour of planting then, that if the winter proves mild new roots are produced, which form a good preparation for a vigorous growth in spring. But this is a point on which all are not agreed, as some think that it is safer to defer the final transplantation till the spring, when there is no danger of the plant being injured by frost.

Plants.—The plants should be put in the ground immediately upon their removal from the nursery-bed. The roots should be left as entire as possible, but the ragged parts should be cut away with a knife, and the head lopped off to make the plant grow bushy. If the wounded parts of the roots be cut into small pieces, and sown in a bed prepared for them, they will produce quicks or thorns the same year, and such a method of propagation is more expeditious than that of growing them from the seed.

In planting hedges it is common to use plants of one, two, or three years old, seldom exceeding this last age. Such young plants, however, are long in growing into a fence, and would be totally destroyed in the interval if not well fenced and nursed. Much time might be saved in the rearing of hedges, and good fences obtained at less expense, if older plants were employed for that purpose. Three years old is certainly the youngest that should be planted, and if they are even six or seven years old so much the better. The prevailing idea that plants of that age will not thrive if transplanted is totally unfounded. In Holland the nurserymen have ready-grown hedges for sale; and these being frequently removed from one spot to another may, almost without hazard of failure, be transferred to a considerable distance and replanted.

Methods of Planting.—A hedge should be planted on the flat, as in Fig. 16, because the thorns, when planted erect, grow sooner into a useful fence, and much less ground is wasted when they are placed in their natural position than when laid sloping. There should be no ditches about a hedge, unless they are actually needed for drainage.

The old bank-and-ditch methods of planting were very expensive, and less successful. In these cases the hedge was planted either on the flat of a bank or on the face or slope of it. A ditch $2\frac{1}{2}$ feet wide at top and 1 foot at bottom, and from 2 to 3 feet in depth, was thrown out and formed into a hedge-mound alongside. When the hedge was to be planted on the flat of a bank, the mound had to be levelled, as in Fig. 17; when

Fig. 16.

Fig. 17.

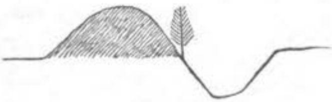


Fig. 18.

Fig. 19.

to be planted on the face or slope of the bank, the mound was shaped as in Fig. 18. Sometimes a double hedge and ditch was formed, as in Fig. 19. Planting on the flat of a bank is, perhaps, the worst of all methods, because not only is the thrown-up soil apt to be poor, but the plants are sure to suffer from want of moisture in dry weather.

Preparation of Soil, and Planting.—Before planting on the flat, the soil in the line of the hedge must be carefully prepared by loosening it to a depth of at least a foot, and ridding it thoroughly of weeds. On poor soils it will be found of great benefit to apply a little garden-mould or well-prepared compost around the roots of the young plants.

The quicksets should be planted at distances of from 6 to 10 inches asunder, according to the quality of the soil, in single rows or in two rows, as . . . . In a good soil there is less difficulty in rearing them, and, consequently, fewer plants are necessary.

Weak plants should not be mixed with the strong ones in a hedge, but kept separate, so that special care can be devoted to them. When the two are mixed, the weaker are impoverished and choked up by the stronger.

It is a pernicious practice, that of planting trees in the line of a hedge. Most trees (such as the oak, beech, and elm) grow faster than quicksets, and when grown in the midst of a thorn hedge spread their roots in all directions, robbing the thorns of their proper nourishment, and soon overshadow them and deprive them of the benefits of sun and air.

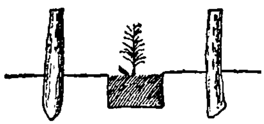


Fig. 20.

Fencing Young Hedges.—The hedge while young must be properly fenced to protect it from injury by animals. This may be done by erecting a double row of posts and rails, four rails in height, after the manner shown in Fig. 20. In some cases a single protecting fence outside the hedge will be all that is necessary. Cheap wire fences are often employed for this purpose instead of posts and rails. Frequently, also, a double or single *dead-hedge* is formed to serve as a fence and guard until the quicksets are grown; in the latter case the quickset may be wattled into the dead-hedge.

Weeding and Cleaning.—The roots of the young hedge should also be kept carefully clean, and the soil around them occasionally stirred. For digging around the roots of the plants a small spade is used, and for stirring and weeding the surface under the hedge the Dutch hoe is commonly employed.

Fig. 21.

Pruning.—During the first year or two, the top of the hedge should be moderately pruned, and the lateral branches suffered to grow untouched. It afterwards becomes necessary to cut them, but they should be left as bushy as possible at the lower part and gradually tapered towards the top. The triangular section, as illustrated in Fig. 21, is proved by experience to be the best form of a hedge, as it approaches most nearly to the natural form of the hawthorn tree, and may be grown to a height of 4 or 5 feet without ceasing to be thick and well-clothed to the very bottom; and such a hedge forms a pleasing, impenetrable, and durable fence.

Fig. 22.

When the converse method of training is adopted, and the hedge is allowed to grow bushy at the top, the plants are almost branchless near the ground, as seen in Fig. 22, and the older this fence becomes it gets more and more useless.

Trimming a Hedge.—With a hedge-bill or switcher, a man will trim a great quantity of hedge in a day. This instrument is light, and easily wielded. The hedger walks forward to his work, close alongside the hedge, with the switcher in his right hand, and uses it with a single upward stroke, from the lowermost to the highest twigs or branches. The left hand is used as a catch or rest for the bill as it descends.

Brush Fork.—For lifting and handling hedge cuttings, a common spreading-fork is sometimes fitted with a board 2 feet long and 6 inches wide upon the handle. This prevents the cuttings from sliding down the fork-handle, as they are otherwise apt to do when the fork is raised upon the shoulder.

Ditching.—When there is a ditch about a hedge, it should be cleaned out or re-dug, and the hedge-bank repaired, at the same time that the hedge is pruned.

Repairing Old Hedges.—On favourable soils quickset hedges, if carefully trained and occasionally cut over or dressed in the wedge shape, will last good for ages. If their original training has been neglected, however, they soon become full of gaps and weak places, in which condition they are an everlasting trouble.

In ordinary-sized gaps between the old stems of a thorn hedge young plants will not easily take root and thrive. This effect is produced partly by the old hedge over-topping and shadowing the young plants, and sometimes partly by the want of nourishment from the soil, the older roots having already extracted much of the elements of fertility.

Plashing.—Gaps in hedges may often be filled up by laying down a long branch or stem of thorn, half cut through near the ground, and fixing it firmly along the surface by notched stakes driven into the ground, and covering the extreme end with a shovelful of earth. This extreme end strikes root, and the horizontal stem or branch throws out upright shoots, which fill up the gap. This, after a short time, makes a good interim fence; but, in the long run, plashing is destructive to the plants, and accordingly there is scarce to be met with a complete good hedge where it has been long practised.

Dead-Hedges.—A better plan of cutting over an old hedge, when there are no gaps, is to cut it close to the ground, and make a dead fence for the temporary purpose of protecting the young shoots which will spring up from the old stumps till they have acquired a sufficient degree of strength to render them fencible without any other assistance. For this purpose the dead-hedge is well adapted, and lasts so long as to enable the live fence to grow up and complete the enclosure.

Dead hedges are of different sorts. Plain dead-hedges are made by cutting the thorns or brushwood of which they consist into certain lengths, and planting them with their but-ends in the ground. These are called plain dead-hedges, in opposition to other descriptions, where more art is used, such as the dead-hedge with upright stakes, wattled, Fig. 23, and the common plaited hedge, bound together at the top with willows.

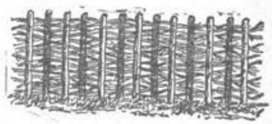


Fig. 23.

The Stake-and-Rice fence is another form of dead-hedge, and is formed of stakes driven into the ground 5 or 6 feet apart, and interlaced with branches set on their but-ends in the direction of the heaviest winds, and each one wound alternately before and behind the stakes. A single rail is often nailed along the top of the stakes as a finish and to afford additional strength to the fence.

Wiring an Old Hedge.—The great drawback to old and badly grown hedges is their want of lateral branches near the ground, sufficient to make it close enough to turn small animals, such as sheep and pigs.

This defect may be remedied without cutting over the hedge by making a combination hedge-and-wire fence, as illustrated in Fig. 24. If the old hedge is very high and shelter is not needed, it may be topped down in the manner shown in Fig. 25.

This method of wiring an old hedge near to the ground, gives an efficient fence, and at considerably less cost than by cutting over and plashing and forming a dead-hedge or other temporary fence to last till the old hedge is re-grown. Wooden rails are sometimes used instead of wires, but the latter are preferable, being more portable, and at the same time cheaper and more durable.

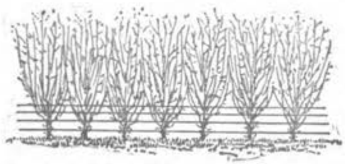


Fig. 24.

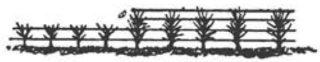


Fig. 25.

Other Hedge-Plants.—Amongst other plants used for hedges are hornbeam, holly, willow, whin or furze, hazel-nut tree, common birch, narrow-leaved English elm, beech, prickly broom, and privet. Hedges are sometimes formed of one of these species only, but often of several mingled together, as of beechwood and privet. None of these plants, however, makes a good hedge for field purposes, as they are either very slow of growth and require a long time to attain a sufficient height for a fence, or else when grown it is not sufficiently defensive at all seasons and will not stand pruning.

Whin Hedge.—The common whin, furze, or gorse, an indigenous evergreen, armed with spines, was formerly much cultivated as a fence-plant, and is so still in some situations. It comes very quickly to perfection, and grows in a soil where few other plants would thrive. The whin-seeds are sown when the ground is fresh and moist, at the rate of about 1 lb. of seed to 200 yards. The best season for sowing is during the months of March and April.

The old method of growing a whin-fence was to sow the seed on the top of a bank. It is best cultivated on the flat, however, for the same reason as the quickset; and the ground should be prepared previous to sowing the whin-seed, the same as directed to be done before planting a quickset hedge.

The whin forms a complete fence the second year after planting. The hedge should be pruned once a year, in the month of June. On attention to this the permanence of the fence very much depends.

Being one of the cheapest fences, and the plant having such facility of growth and fitness for the purpose, it may be asked why the whin is so little grown as a hedge-plant? The chief reason is its want of durability; for although a native plant, and, under certain circumstances, hardy, it is very liable to be destroyed by frost. It cannot, therefore, be depended upon as a permanent fence. Its duration, indeed, can be greatly prolonged by regular pruning, but under the best management it makes a comparatively short-lived fence.

Hornbeam Hedges.—In Germany they plant hornbeam in such a manner as that every two plants may be brought to intersect each other in the form of a St. Andrew's cross. In that part where the two plants cross each other the hedger gently scrapes off the bark and binds them with straw thwart-wise; here the two plants consolidate in a sort of indissoluble knot, and push from thence horizontal shoots, which form a sort of living palisado or *chevaux-de-frise.*

Willows, when grown as a hedge, are also planted cross or lattice-wise, and bound along the top.

Osage Orange Hedges.—In some parts of the United States the osage orange is much grown as a hedge-plant, but though it is a rapid grower and shoots up erect, it is so open below that it is worthless as a fence against sheep and pigs, and even small cattle, unless it is wired or railed near the ground.

CHAPTER X.

DYKES OR WALL FENCES.

SINCE hedges are not available for use as fences until they are several years old, they must be left out of account where an immediate fence is wanted, unless the Dutch plan of planting ready-grown hedges be adopted. Moreover, in those districts where the greatest proportion of land has to be reclaimed, both soil and climate are unfavourable to the satisfactory rearing of hedges. In such places, however, stone is generally abundant, and can be used in the construction of dykes, which are better adapted to a high country than any other description of fencing.

Lime-built walls, owing to the great expense of them, can only be of limited application on the farm, but dry-stone dykes can be erected at a moderate cost. Where lime is abundant it is a good plan to set the cope-stones in mortar, for if the wall is well constructed the top stones, which are the most liable to be moved, are thus firmly secured.

A dry-stone dyke may be considered a permanent fence, because the materials never decay, and it has this advantage as compared with a hedge, that it is of immediate use. A well-built dyke will stand many years without requiring any repairs, and with a little expense in later years to keep it in order it will last a whole generation without requiring to be rebuilt.

When the stones are dug out of the ground, especially if they are of a gritty or brittle nature and show a tendency to split, they should be carted to the site of the dyke in the autumn and left unbuilt until the spring. They will thus be subjected during winter to the influence of frosts and of the atmosphere, the effects of which will be the disintegration, complete or partial, of the undurable stones, which can be thrown aside at the time of building, The neglect of this precaution often shows itself in the crumbling down of comparatively new-built dykes, and the builder is generally blamed for carelessness in neglecting to pack or pin his work sufficiently, when in reality the blame consists in providing him with bad and untried stones.

A dry-stone dyke on arable ground is generally built about 4 or 4½ feet in height. On hilly ground, where it is intended as a fence against sheep, and shelter is much needed, it should not be less than 5 or 6 feet high. The dimensions for a dyke 5 feet in height are about 27 inches broad at the base and 14 inches at the top. The foundation-stones should be large, and the inequalities of the ground should be smoothed with a spade, so as to provide a solid bed before they are laid. A selection of stones is not always possible, but where they are available those of a flat shape with a rough surface should be chosen, as they are laid on their natural beds and do not require pinning. Small stones are useful, and indeed necessary, where materials are undressed, but the builders should not be allowed to pack them all into the heart of the wall. Such a practice leaves the wall without bond, and unfit to stand for any length of time. The large and small stones should be uniformly mixed throughout the wall, so that in every part of it they may break bond as much as possible. There should also be one or more through bond-stones in the height of the wall, built in at every few feet of the length. The body of the wall is surmounted by a flat cover, on which the cope-stones are set on edge.

The quantity of stone required to build one lineal yard of a dyke 5 feet in height is 0·95 cubic yards, or

Fig. 26.

95 cubic yards of stone to every 100 lineal yards of dyke. The building alone, which is all the cost incurred when the stones have to be taken off the land, can be done for *7d.* to *8d.* per lineal yard; but the total cost, when the stones have to be specially provided (including quarrying, or digging them out of the ground when they cannot be obtained on the surface, carting them to the site, and building the wall), will be found to vary from about 1*s.* 3*d.* to 1*s.* 9*d.* per lineal yard. One man can build 6 yards of dyke in a day, working

by himself; but the work is best done by two builders working together on opposite sides of the wall, as by this method a better bond can be obtained than when the two sides are alternately raised. A wooden frame of the dimensions of the dyke is used as a guide by the builders. This description of fence, and the method of building it, is shown in Fig. 26, the illustration being a reproduction from Stephen's "Book of the Farm."

Haulage of Stone.—When the stones are quarried on the ground, or can be gathered off the field, they are easily conveyed to the site of the dyke upon a stone-boat or sledge. This is particularly the case when the loads have to be drawn down hill and on steep ground, where wheeled vehicles are employed with difficulty and inconvenience. Moreover, the stone-boat is easier loaded and unloaded with large stones than a high-sided cart.

Galloway Dyke.—The Galloway dyke owes its name to the circumstance of its having been originally introduced into use in Galloway. It is built without the use of lime or mortar, the same as the dyke already described. Two-thirds of its height, from the surface upwards, is regularly and evenly built on both sides, well filled-in, or packed in the heart, and tied or strengthened at short intervals by long stones reaching from side to side, called thorough-bands. When this first portion of the wall is finished and regularly levelled at the top, the upper third of its height is built of long rough stones, laid across the wall or dyke, having firm hold of each other laterally, but not packed in the heart, the largest stones used in the lowest course, and gradually diminishing to the top. A few inches of additional height in the open work of the Galloway dyke adds very little to the expense.

If well-built and of durable materials, the Galloway dyke will stand good for 20 years without need of repairs. It is peculiarly well adapted as a sheep fence for the Highlands, or all mountain pastures; but it is less suitable for low ground and as a fence against cattle.

Turf Dykes.—Where stones and timber are scarce and expensive, a turf dyke is sometimes of service. Fences of this class are not unfrequently erected as plantation fences in preference to others, chiefly on account of the material they are formed of being found ready to hand on the spot. Mr. C. Y. Michie, who, as forester to the Earl of Seafield, has had large experience in the erection of turf dykes around new plantations, informs us that his practice is as follows:—"On commencing to erect a turf dyke a line of poles is set along the centre of the line of fence, from which the basement is marked off on each side two feet, the whole base of the dyke being 4 feet. The height of the dyke above the ground surface is 4 feet, and its width on the top 20 inches. A ditch 4 feet wide at the top, 2 feet wide at the bottom, and $2\frac{1}{2}$ feet deep, is usually formed on the front or outer side of the dyke. The turfs of which the dyke is built are cut 8 inches broad and as deep as the soil will admit, and are set on edge with the grassy side outwards, their position corresponding with the slope of the dyke. After the first row of turf is set up as much earth is excavated from the ditch and thrown to the back as will level the surface fully as high as the top of the turf. After the backing is firmly packed and levelled, another layer of turf is set up, and the same process of filling and levelling again repeated, observing always that in placing the turfs the joinings do not come opposite each other. The cost of building a turf dyke of the dimensions given is from 6*d.* to 7*d.* per lineal yard."

The turf dyke is often constructed in a hasty and careless manner, in which case it soon moulders down. When the sods are carefully cut and attentively laid, each course made to cover the seams or joinings of those immediately below, together with ties or thorough-bands at frequent intervals, and the whole properly packed in the heart, with a sufficient coping of long sods on the top to keep out rain, this fence is tolerably durable.

When the turfs are set on edge instead of laid flat, the dyke lasts considerably longer without requiring to be rebuilt. The best and most durable turf for dykes is that which contains most solid earth; and the least durable that which contains most vegetable matter. After laying it up in heaps for a time the latter becomes a decomposed, soft, and pulpy mass. This change is especially apt to take place with turf in a dyke if laid in a horizontal position, one layer above another.

Frequent repairs are necessary, but if these are carefully executed every spring, and when any breach occurs, the turf dyke will occasionally answer a good purpose in particular situations, more especially as the original expense is very low.

CHAPTER XI.

WOODEN FENCES.

OPEN wooden fences are less suitable to a high, open country than hedges or stone dykes, but in a low country they have many advantages to recommend their use. They occupy very little space, and are favourable to a free ventilation—two points which deserve special attention where land is valuable, and in thickly wooded districts. The chief objection to their use lies in their temporary character, which arises from the liability of the materials to decay, and often also from defective and unsubstantial construction. Yet as a protection to young hedges, in districts where timber is plentiful, a wooden fence is often more economical than any other.

Wooden Paling.—The common wooden paling consists of horizontal rails nailed to posts or stakes placed vertically and driven into the ground, as shown in Fig. 27. It may be made with either three or four horizontal rails. The latter number is preferable and necessary where sheep are feeding.

The rails are formed either of sawn or split wood. When the trees are small they may be split, but when they are of sufficient size they should be sawn.

Larch, spruce, or any other kind of fir or pine-wood, is commonly used, but larch is best, especially for posts, unless they are of hard wood. The posts are made about

6 feet long, and sharpened to a point. They are driven into the ground with a mall, to the depth of 8 inches, and set 6 feet apart. The horizontal rails are nailed to the posts.

A paling of larch-wood, having posts 6 feet apart, and four rails in height, can be erected at a cost of about 3*s*. 6*d*. per rod, or 7½*d*. per lineal yard.

Preservation of Wooden Posts.—It has long been a practice to burn or char that part of the posts or standards intended to be set or driven into the earth, as a means of rendering them more durable; but the best defence against the decay of the posts is to leave

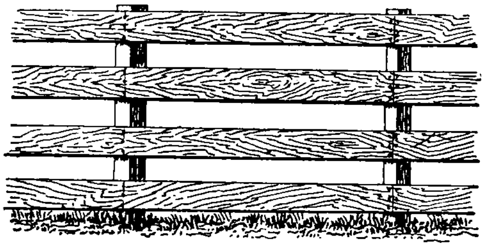


Fig. 27.

the bark on at that part which is to remain immediately above and below ground. Other remedies are also employed at times to prevent the decay of the posts—such as dipping the points that are to be driven into the earth into a solution of boiling tar, melted pitch, or gas-liquid. A friend of ours gives the following recipe: "Take boiled linseed oil, and stir in pulverized coal to the consistency of paint. Put a coat of this over the timber, and there is not a man alive that will live to see it rot." The posts should be completely dry before they are dipped in any of these preparations; for if they are either made of green wood, or have imbibed much moisture, the expansion of the moisture will bring off the coating; whereas when they are made of well-seasoned wood, and are at the same time perfectly dry, and the pitch boiling hot, it readily enters the pores, and, by filling them completely, prevents the access of moisture, and consequently the injurious effects caused by it.

Driving Fence Posts.—All the posts should be driven into the ground deep enough to be beyond the risk of their being lifted by frost. This attention is especially needful on soils that are liable to heave.

The usual method of driving fence-posts and stakes is to strike them on the upper end with a heavy wooden mall; but in the operation many of them get split at the top and are soon destroyed. To drive the posts without injury, use a piece of hard wood scantling, 12 inches long by 6 inches broad, with a handle 3 or 4 feet long attached to it. A boy lays this scantling on the top of the post to be driven, and retains his hold on the handle until the driving is completed. He then moves the scantling to the next post. This device entails but little extra trouble or expense, and by its adoption the posts and stakes remain much longer durable and in good condition.

Driving Long Stakes or Poles.—For driving hop or other long poles, which are usually set by making a hole with an iron bar and forcing into it the lower end of the pole, another device is recommended. This is to take "a block of tough wood, 1 foot in length, 4 or 5 inches square at the top, made tapering, with the part next the pole slightly hollowed out. Then wind a trace-chain closely about the block and pole, and hook it in position. With a sledge-hammer, or beetle, strike heavy blows upon the block. Each blow serves only to tighten the grip of the chain upon the pole. In this way quite large poles or stakes may be quickly driven firmly in the ground. To keep the chain from falling to the ground when unfastened from the pole, it should pass through a hole bored through the block."

Post-hole Borer.—The earth-borer illustrated in Fig. 28 is a valuable labour-saving tool, and worthy the attention of all engaged in the erection of fencing. It is suitable for most kinds of soil, or for all purposes where a number of holes have to be bored in the shortest space of time.

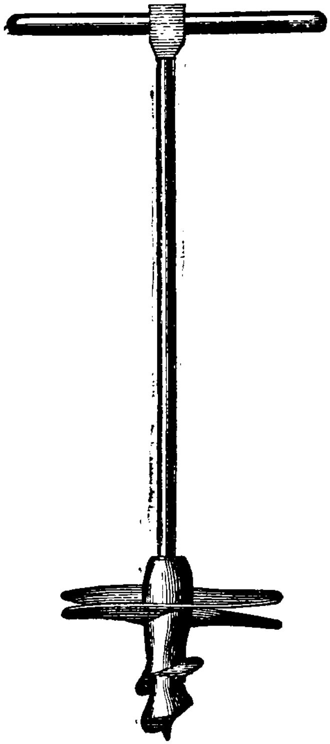


Fig. 28.

It lifts the soil from the hole without the necessity of using spades. After five or six revolutions 6 to 10 inches of earth will be gathered in the wings of the borer, which must be raised and shaken off. In stony ground it is necessary to move the borer to and fro after two or three revolutions. Small-sized stones go through the wings of the borer, but the larger ones must be removed by hand or in other manner. The German, Austrian, and Russian Governments have adopted the borers for placing palisades; and the Royal Prussian Telegraph Company use nothing but the Patent Borers for boring the holes for their posts.

The borers vary from 3 to 18 inches in diameter, and cost from 11*s*. 6*d*. to 45*s*. each. They may be obtained from Messrs. F. Morton and Co.

Post-hole Digger.—A post-hole digger much used in America for this purpose, as well as for planting trees, is illustrated in Figs. 29 and 30. The principle on which it works makes it self-cleaning, and prevents adhesion in sticky soil; therefore it always works freely and easily. It works well in stony, sandy, or clay soils; and quicksand under water is as easily removed by it as if no water existed.


Fig. 29.

Fig. 29 shows the digger with the blades open, ready to be plunged into the ground. Fig. 30 shows the instrument as it is drawn out after grasping the sand or dirt.

One man with this digger can do much more work, in a given time, than with a bar-and-post spade; and anything that can be loosened and reduced to 5 inches or less in diameter can be easily removed by it. As constructed for ordinary use it will dig readily 4 feet deep.

The mode of using the digger is as follows:—Plunge it into the ground, as shown in Fig. 29, and when the soil is loosened, pull out the lever with one hand, as shown in Fig. 30, which will press the dirt between the blades; then draw the digger from the hole, keeping hold of the lever with one hand and the handle with the other. When the digger is clear of the hole, by simply pressing down the lever, which will open the blades, the dirt will fall from between them. The digger is then ready for another plunge. The steel blades are 9 inches long, and the whole tool 5 feet long. The price is 20*s.*; and the instrument may be obtained from Messrs. Bayliss, Jones, and Bayliss.

Fig. 30.

Post-and-Rail Fence.—In this kind of fence the posts are usually formed of cleft oak, 5 feet 6 inches in length, with four holes for rails, as shown in Fig. 31, and the bottom portion, which is fixed in the earth, is charred to prevent decay. The general sectional dimensions of the posts are $6\frac{1}{2}$ inches by $3\frac{1}{2}$ inches.

They are made more bulky at the lower end than the upper, and are fixed in the ground by digging holes, 2½ feet deep, placing them therein, shovelling the soil in, and ramming it around the posts till they be firmly fixed.

Fig. 31.

The rails are generally from 3½ to 4 inches broad, and about 2 inches thick. The distance between the posts is 9 or 10 feet.

Such a fence, having oak posts and rails, and four rails in height, will cost about 1*s*. per lineal yard.

Being very strong, these fences are suitable for enclosing cattle and horses. A good point in their construction is that each rail or bar is independent of the others, and can be taken out or replaced without much trouble, unless the rails are nailed or pegged to the posts, which is unusual.

It takes, however, a large amount of labour to mortice the post and fit the bars or rails, and the fence can only be erected with advantage in districts where timber is abundant and cheap.

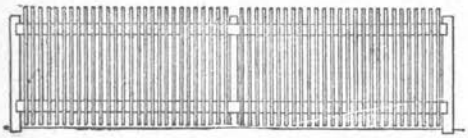


Fig. 32.

Upright Spar Fence.—As a garden fence, or for confining poultry, an upright spar-wood fence, like that illustrated in Fig. 32, will be found both effectual and cheap, where something more ornamental is wanted than for ordinary field purposes. It is made by fixing perpendicular posts in the earth, nailing two rails of wood horizontally, one near the ground and another near the top of the posts, and covering these with spars nailed on upright, the spars not being above 2 or 3 inches broad.

Loose Rail Fences.—A primitive fence may be formed without nails or ties of any sort by inserting the stakes in the ground in different directions, and by using forked or hooked stakes. They are out of place in old settled countries, but may be found useful in pioneer farming. In America a still more simple fence is commonly met, even in districts that have been settled for a generation or more. It is known as the "Virginia crook," or worm-fence, and consists of nothing but cleft rails, similar to those employed in the cleft post-and-rail fence, and these are laid down in zigzag fashion, and one rail placed above another to the desired height, no posts or stakes and no nails being used. It forms a very strong fence, though a rough one, but it occupies a great deal of ground. It is, however, easily taken down and rebuilt again, while it will turn any and every description of stock.

CHAPTER XII.

WIRE FENCES.

The construction of wire fences has of late years greatly extended, the portability and durability of the wire rendering its employment more convenient and profitable than the use of wooden rails or any other description of fencing.

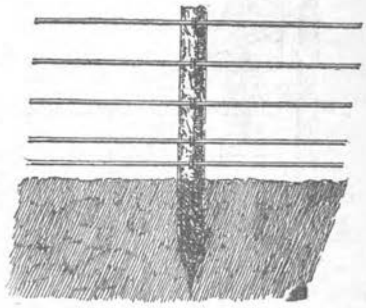


Fig. 33.

The wire fence most in use for farm purposes has all the straining and intermediate posts of wood, as in Fig. 33, and the wires are strained by a portable strainer. This system is far from satisfactory, because the wires are seldom

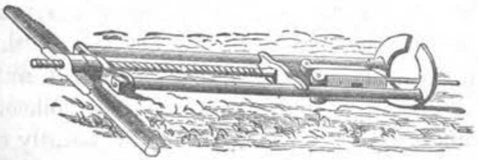


Fig. 34.

well strained, and when the posts begin to decay the whole fence gets loose and worthless. Fig. 34 shows an improved form of portable strainer, used in the erection of such fences as the one here described. The wires are fastened to the posts, both terminal and intermediate, by means of galvanized wire staples. A fence of this kind, with wooden posts 6 feet apart, and having 5 single wires in height, costs about 8*d.* per lineal yard.

A much more substantial wire fence with wooden posts is illustrated in Fig. 35. In this case there are

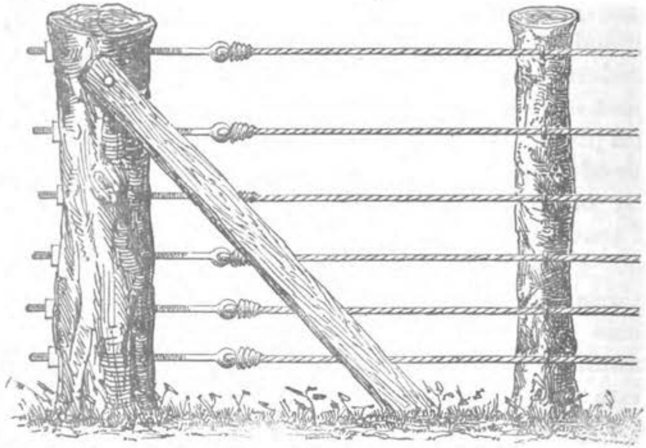


Fig. 35.

6 lines of wire, and each line consists of a 3-ply strand. Instead of the wires being fastened to the terminal by staples, holes are bored through the post in the lines of the wires, and straining eye-bolts with nuts and washers are attached for tightening up the fence. The same strand wires as the above are frequently erected on iron posts and pillars, for which the eye-bolts are equally adapted. Fences of this description are, however, too expensive for general farm purposes, and are

only erected as roadside fences, or in other situations where a fence of extraordinary strength is required.

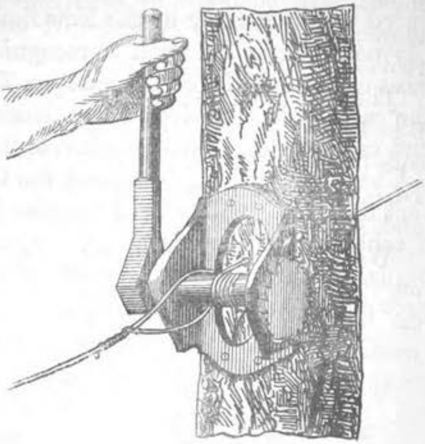


Fig. 36.

A further improvement in the erection of wire fences has been reached by the introduction of the winding bracket, illustrated in Fig. 36. It is likely to entirely supersede the use of the screwed eye-bolts and of portable strainers, and is equally suited for applying to iron and wooden pillars or posts. The winders vary in price from 1*s.* 4*d.* to 3*s.* 6*d.* each.

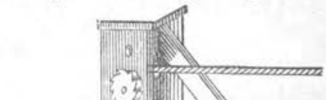


Fig. 37.

Straining - pillars and posts fitted with these winding brackets are now extending in use. An iron straining-pillar of this kind is illustrated in Fig. 37.

Corrimony Wire Fencing.—The Corrimony fence was originally introduced to this country by the New Zealand colonists, and has now gained for itself a recognised position as the most economical fence for sheep. This is particularly the case in hilly districts, where the expenses of carriage and erecting tell heavily against ordinary fences.

The distinguishing feature of the Corrimony fence is that the fixed standards (of wood or iron) are placed at a considerable distance apart, varying from 12 to 22 yards, and that in the intervening space the wires are prevented from being pushed apart by being fixed to

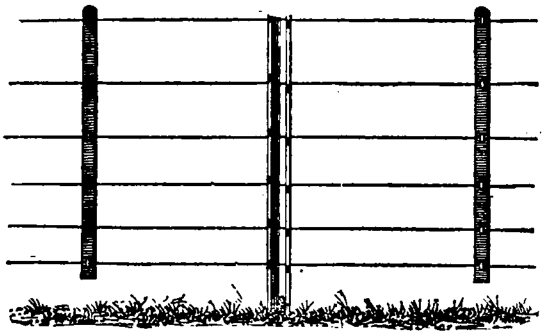


Fig. 38.

"droppers" placed at intervals of 6 feet. These droppers do not go into the ground, so that the fence possesses a certain degree of elasticity in a lateral direction between each pair of standards. The droppers can be either made of iron or of wood, but must be very light, so as not to overload the fence.

Fig. 38 shows a Corrimony fence, by Bayliss, Jones, and Bayliss. The standards are of angle-iron, and are punched on a patent principle which admits of the wires being fastened without threading. Fig. 39 is an enlarged view of this standard, showing the recesses for the wire. There are 6 lines of steel wire, and a light iron dropper every two yards. The cost of this fence, exclusive of straining-pillars, is 7*d.* per yard, or £42 5*s.* per mile. A straining-pillar will cost about 32*s.* 6*d.*, and one is required for every 250 yards.

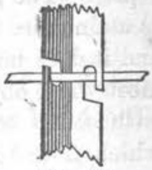


Fig. 39.

The wires are fastened to the iron droppers in the above fence by means of self-acting tongues or clips, and when the lines are erected they are placed in the tongues, which are closed with a hammer as soon as the fence is drawn taut. Fig. 40 is an enlarged view of dropper showing tongue fastening wire.

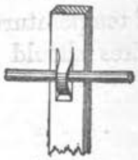
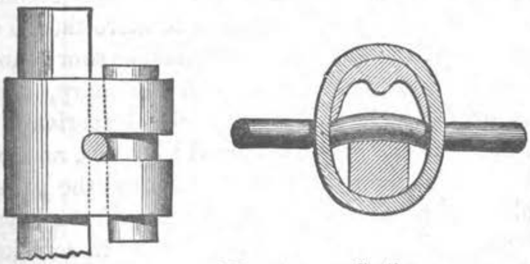


Fig. 40.

Fig. 41 shows full-sized section and side view of A. and J. Main and Co.'s "vice-grip" dropper, with wedges and clips complete, and the wire fixed.

When wooden droppers are used the wires are fast-


Side View. Fig. 41. Section.

ened by small staples, or passed through holes bored for the purpose, and secured with wooden wedges.

Barb Wire Fencing.—Steel barb fencing has of late years been extensively adopted in preference to plain wire fencing, in consequence of the deficiencies of the latter in so many respects. The single wire snaps in cold and sags in heat, and the fence soon falls out of repair. The plain single wire is not sufficiently visible to animals, so that they often run against it by accident, and it does not repel the roving and venturesome. To meet these objections the principle of arming the wire with sharp barbs or spikes originated in 1873, since which time barb fencing has been the object of many improvements.

Barb wire fencing should consist of at least two barbs, used in connection with two wires twisted together for the sake of strength, and the better to resist all changes of temperature. The barbs used in connection with two wires should not be twisted around both of them, but

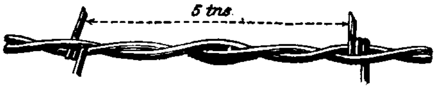


Fig. 42.

pass between them, in order to prevent their becoming loosened, and the barbs should not be more than 5 or 6 inches apart (Fig. 42). The barb must be short enough not necessarily to tear the animal. A sharp, instantaneous prick is all that is needed. Experience has shown that wire fences unprotected by barbs, no matter what the size of the wire, cannot withstand the pressure of a full-sized ox or horse, and the only effectual resistance is in the sharp prick of the barb used in connection with the wire. And further, a barb which is not sharp enough to prick and repel at the moment of contact invites further pressure by the animal rubbing its body against it, which results in destroying the fence.

Barbs two in a group are considered equally as effective as four in a group, for the reason that barbs used two in a group, in combination with two wires, are caused by the twisting of the wires to project in every direction, so that it is impossible for any animal presenting one foot of surface to press against a wire thus armed without being effectually met by a point.

The number of barb lines or wires to be used must be decided in each case by the special object of the fence. One line 4 feet from the ground will turn cows, oxen, and horses. Two lines 21 inches from the ground and from each other will turn smaller cattle as well as the larger ones. Three lines, the lowest 12 inches from the ground, the next 24 inches, and the third 42 inches from the ground, will accomplish all named above, and make a thoroughly good and substantial farm fence. Four, five, and even six lines are frequently used when some special object is in view, such as excluding dogs, pigs, and other small animals, in which cases the lower lines are placed nearer to the ground and to each other than are the upper lines.

With cattle the great advantage of barbed wire is that it keeps them in; with sheep, it keeps their enemies out (Fig. 43). This is a very substantial fence, erected by Felten and Guilleaume. In some districts the havoc made amongst sheep by prowling dogs is immense, but steel barb fencing, properly erected, is dog-proof.

Many combinations can be formed with barb fencing and other styles of fence. One line or wire on the top of any wooden fence makes a structure cattle will not molest. One or two barb wires put up with the old plain wire, or entwined in the line of a hedge, makes a magical change in the efficiency of the whole.

In large quantities barb wire, double strand, and with the barbs 5 inches apart, costs less than one penny per yard.

We have seen a fence of this kind in America, but with three lines of wire instead of four, and with the posts 50 feet apart, which was apparently effective

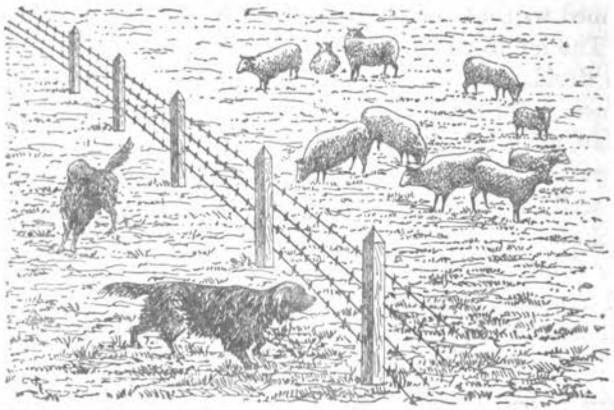


Fig. 43.

against cattle, and cost on a large contract only £25 per mile, or about $3\frac{1}{4}d.$ per yard.

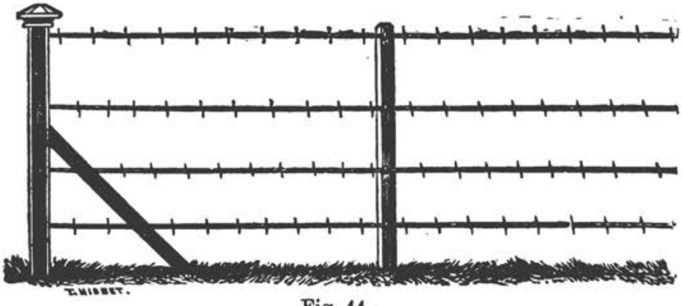


Fig. 44.

Fig. 44 shows a barb wire fence with iron standards, as erected by A. and J. Main and Co. The terminal is a winding-pillar, and tongues are cut at the backs of the  wire standards, along which the wires are passed, and after being strained the tongues are clasped down by the stroke of a hammer, thereby securing the wires effectually in their places. The fence is usually made with four lines of galvanized steel barb wire, the standards 10 to 20 feet apart. The cost of such a fence varies from £64 to £50 a mile.

Iron Bar Fencing.—Fences of this description are too expensive for ordinary farm purposes. For surrounding parks and pleasure grounds, however, and as road-side fences, they are much in demand, as they present a good appearance combined with great strength

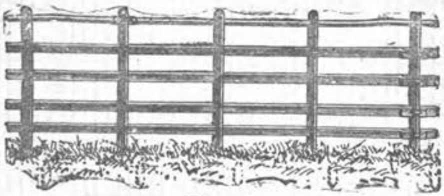


Fig. 45.

of resistance to the pressure of the large animals which is frequently brought against them in such situations.

Iron bar fencing is of various kinds, as flat or round, solid or tubular bars. The usual mode of constructing bar fencing has been upon the principle of having the horizontal bars all jointed at one standard—an arrangement opposed to sound mechanical principles, and which is now improved upon by Messrs. A. and J. Main and Co. In this new "break-joint" construction, the top bar is jointed at a different standard from the lower bars, as seen in Fig. 45, thus distributing or breaking the pinnings, and securing to the fence its full lateral stiffness.

Unclimbable Strained Wire Deer-Fence.—Fig. 46 shows an elegant and effective fence for surrounding or subdividing deer-parks. Many miles of this description of fence have been used in surrounding the Royal parks at Windsor. It is 6 feet high above the ground, with standards 1½ inches by ⅜ths of an inch, 9 feet apart, having anchor-formed and double-pronged feet alternately, 18 inches below ground. The straining-

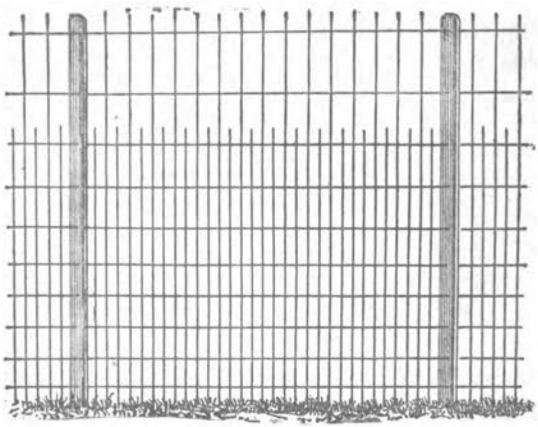


Fig. 46.

pillars are of cast-iron, prepared to fix on stone, each fitted with a double stay, and placed 100 yards apart. The horizontal wires are ten in number, and upon these are placed vertical wires alternating in length, as shown in the engraving, and placed 1¼ inches apart in the lower part of the fence, thus rendering it perfectly game-proof and unclimbable. These wires are laced upon the horizontal wires, and are pointed at the top. A fence of this kind can be erected at a cost of about 8*s*. 6*d*. per lineal yard.

Wire Netting.—Galvanised wire netting is now largely used for enclosing paddocks and turnip fields, &c., or for fencing rabbit-warrens, poultry-yards, pheasantries, &c. Three-inch mesh netting, 3 feet wide or high, costs $4\frac{1}{2}d.$ per yard; 4 feet wide, 6*d.* per yard.

Fig. 47 represents the mode of erecting wire netting, devised by Lord Elcho, the present Earl of Wemyss, for preventing rabbits burrowing under it. A is a separate strip of galvanized wire netting, 6 inches wide, and 2-inch mesh, which is laid flat on the ground on the side of the fence from which rabbits come, and

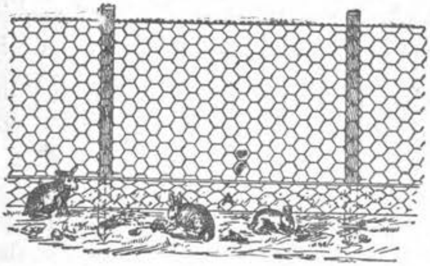


Fig. 47.

attached here and there to the upright netting. The grass, fallen leaves, &c., soon conceal the netting thus laid down, and the rabbit vainly scratches upon it, his intelligence failing to teach him to begin his tunnel farther back. The strips cost about 6*s.* 6*d.* per 100 yards, including a proportionate quantity of soft tying-wire.

The old modes of fixing wire netting around rabbit burrows, &c., are to dig a trench 6 inches deep and more, and drop the netting into it, or to fill the trench with broken stones or concrete; but these methods are both troublesome and expensive.

When extra strong netting is required, it is secured with one or more centre 3-ply strands. As a kangaroo fence in Australia, where galvanized wire netting is now extensively used for this purpose, the meshes are 6 inches wide, and at least two centre 3-ply strands are added for additional strength.

For poultry fencing, galvanized wire netting on strong iron frames, standing 6 or 7 feet high, is commonly used. Such a fence costs 3*s*. to 4*s*. per lineal yard, and answers well for enclosing the poultry yard, but in other quarters a cheaper fence against poultry will be equally efficient.

Where pheasants are reared, the fence is usually made about 7½ feet high, and the lower half is covered with galvanized corrugated sheets, to prevent foxes disturbing the birds, and the upper half with galvanized wire netting.

CHAPTER XIII.

MOVABLE FENCES.

UNDER this head are comprised all the different kinds of hurdles, and also sheep nets, which are in use for shifting folds in feeding off root and green crops or grass, and which are likewise extremely useful and convenient at times for temporarily dividing a field—as when one part of a field is left in pasture for grazing and the other part is brought under crop culture.

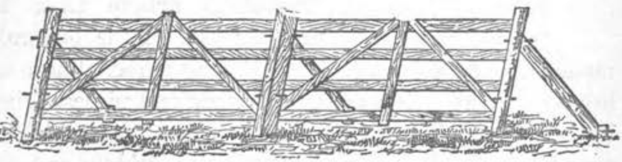


Fig. 48.

Hurdles may be divided into various classes, as wooden and iron, open and close, sheep and cattle hurdles, &c.; but it will be sufficient to notice briefly a few of the varieties most in use.

Scotch Hurdle or Flake.—This hurdle, as seen in Fig. 48, consists of two posts, each 2 × 3 inches and 4½ feet long, having the lower ends long and pointed for entering the ground, four rails, one brace, and two diagonals. They are made of larch or fir-wood, the usual dimensions of the hurdle being 9 feet long and 4 feet high. The cost is about 2*s*. each. The mode of setting them is to let the hurdle incline away from the sheep, a rance or stay being placed between every two hurdles to keep them in position, with a wooden peg or pin fastening one end of the rance to the hurdle, and another peg driven through the other end of the rance into the ground.

The flake is, withal, a clumsy and weighty hurdle. To move a number of them any distance in a field they must be put on carts, and a single-horse cart can only carry a dozen of them conveniently, while they are easily broken in the process of unloading. When set in position, too, they are very liable to be blown over by high winds, from the amount of surface exposed by their flat bars.

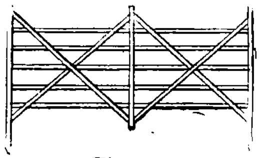


Fig. 49.

English or Welsh Hurdle.—The English wooden hurdle is a lighter, cheaper, and more convenient article than the Scotch flake. It is generally made of split oak, and is very tough and almost unbreakable. It consists of two upright end pieces, joined by four or five mortised bars 7 to 9 feet long, which are strengthened by an upright bar in the middle and two or more diagonals. The end pieces are long, and pointed for setting into the ground, which is done with an iron crowbar to avoid driving and splitting the top.

Sometimes they are made with the two sides to answer either as top or bottom, Fig. 49, by which means, if a leg is broken off, it is only necessary to turn the hurdle upside down to have still a perfect hurdle.

These hurdles are set erect, and no rance or stay is used, the ends of the two adjoining hurdles being simply connected by means of a withe band passed over them.

In exposed situations it is sometimes the practice to wattle either furze or straw between the bars of such hurdles as are set to windward.

Wattle Hurdles.—Wattle or close hurdles, made of hazel rods, afford a good shelter to sheep, and are very light to handle, and tolerably durable. They are made about 7½ feet long and 3 feet high, consisting of ten vertical stakes, the two end ones of which are stronger, and project both above and below the hurdle. The lower end is pointed for entering the ground a short way, and the upper end is for receiving the shackle which fastens the ends of two adjoining hurdles to the stake which is driven into the ground between them. The hurdles are closely wattled with rods. The price of these wattle hurdles is 10*s*. or 12*s*. a dozen in the copse districts, out of which they can seldom be obtained.

The stakes used with the wattles are cut 6 to 7 feet long, and sell at about 4*s*. per hundred. They are pointed, and let into the ground by an iron crowbar or stake-pitcher between two of the hurdles, and a shackle of twisted rods is put over it and the projecting heads of the adjoining hurdles to hold the whole together.

Rack Hurdles.—Hurdles of this class are used in feeding off vetches, clover, and other crops which it is not desirable that the sheep should run over while feeding upon. They are placed against the crop, and the sheep eat through the bars, the hurdles being shifted forward once or so every twenty-four hours. When fresh food is required the hurdles are drawn forward a yard or so, and are not fixed in the ground, but are placed in a leaning position, resting on stays, as shown in Fig. 50. The hurdles are connected by means of a shackle. The crop is fed off in the direction in which make the top of the net run uniformly throughout its entire length." When more than one length of net

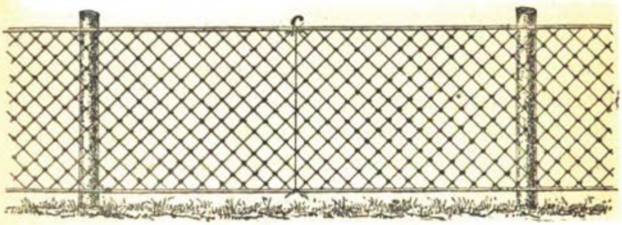


Fig. 56.

is required, the ends of two nets are joined, as at *c*, Fig. 56.

"The shepherd's knot is made in this way. Let *a*, Fig. 57, 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, care being 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. 57 the rope *d* was uppermost

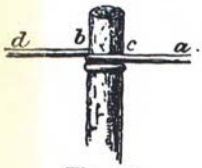


Fig. 57.

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." *

These cord nets, in 40-yard lengths, and 3 to 3½ feet wide, cost, in Scotland, about 12*s.* 6*d.* each, or 3*d.* per yard. Tarred sheep-netting, of the same material, in 50-yard lengths and 4 feet wide, costs in London £1 13*s.*, or nearly 8*d.* per lineal yard. Cocoa-fibre netting, tarred, in 100-yard lengths, 4 feet wide, costs in London £1 15*s.*, or nearly 4½*d.* per lineal yard. These prices do not include stakes for fixing the nets.

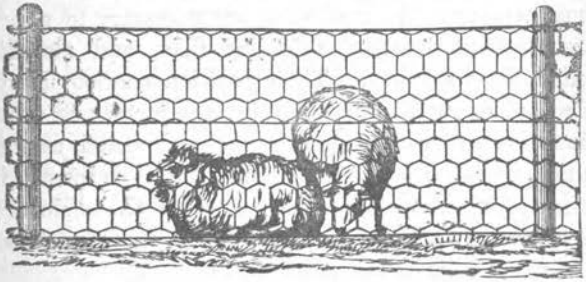


Fig. 58.

Wire Sheep-Netting.—Galvanized wire netting being more durable than the cord nets, is coming largely into use among flockmasters in lowland districts. It is made by A. and J. Main and Co. in 25-yard rolls, and with a 4-inch mesh, and standing 3 feet high (Fig. 58), costs about 5½*d.* per yard. Stakes for fixing the netting are extra.

* Stephen's "Book of the Farm."

CHAPTER XIV.

FIELD GATES.

GATES of one kind or another are necessary to afford communication between field and field, and also for opening on roadways. Their position cannot always be decided on without considering the roads and other communications with which they are connected, as well as the size and shape of the field; but it is mostly in the line of the headland at a corner of the enclosure, and in steep ground more commonly at the lower than at the upper part of the field.

No field gate should be less than 10 feet wide, to permit the free passage of loads of hay and straw, and of traction-engines, field-rollers, and other implements and machines.

Wood and iron are the materials of which gates are constructed, and farm gates in particular are most commonly of the former.

All farm gates should be supplied by the landlord, who should always have a stock of ready-made gates on hand, and give out a new one whenever a tenant sends in the remains of an old worn-out gate.

Wooden Swing Gates.—A good form of wooden gate, by Blenkarn, is shown in Fig. 59, with the iron-work and other portions drawn to a larger scale.

Hanging a gate on wooden posts is a matter of some difficulty and importance. The posts should be heavy, 8 inches square, planted 4 feet deep in the earth, firmly rammed around, and as little higher than the gate as possible. The gate should be hung so that it can only swing one way, and it should open inwards to the field, and not to the road.

To set the posts so that they will remain upright and prevent the sagging so common in field gates, dig the holes the usual depth, but open the whole length of

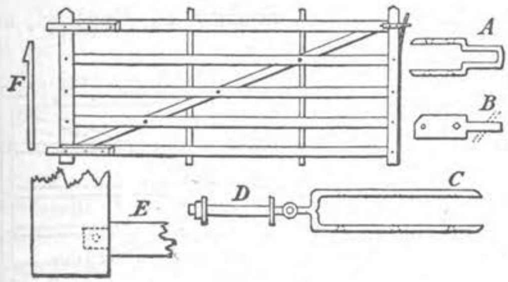


Fig. 59.

A Clasp for spring-fasteners.
B Side view.
C Hinge strap.
D Hook and bolt through post.
E Shows rail-tenon and method of pinning into heel of gate.
F Hook or gate-fastener.

ground between post and post. Place the posts in position, and then lay a stout slab or plank in the bottom of the open trench, with an end pressing firmly against each post. Over this plank fill in the soil to within a foot or so of the surface, beating and ramming it firmly all the while. Then lay another slab, fitting closely to both posts as before, and fill in the remaining soil above it. In soils liable to slip or heave, a stay should also be put in at the back of each post, 2 feet or so below the ground surface. Gates so hung will never sag.

Folding Gates, made in two parts, are sometimes used for wide spaces, where one gate occupying the whole would be too large and heavy. The great objection to them is that, without a centre-post, which is always inconvenient in a gateway, they cannot be steadied, and soon sag, from the constant wobbling or from people climbing upon them.

Wrought-Iron Gate and Posts.—Fig. 60 represents a wrought-iron field gate, manufactured by Messrs. Hill and Smith, which has obtained the silver medals of the Royal Agricultural Society of England, and of

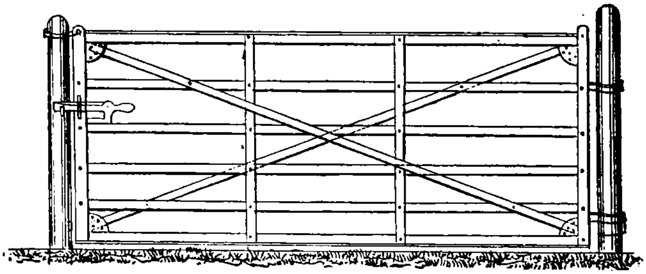


Fig. 60.

the Royal Agricultural Society of Ireland. It is constructed principally of angle and T-iron, which impart great strength and rigidity to the gate without a corresponding increase in weight, and it is hung to the post by thimbles, as shown in the engraving, which slip over the top of the post. The posts are of solid wrought-iron, with basements of plate iron so disposed as to have great holding power in the soil, and quite sufficient, when well rammed in stiff soil, to carry the gate without either stone or wood blocks.

The price of this gate, with posts and hangings complete, is £3 7*s.* 6*d.*; without posts, £1 7*s.* 6*d.*

Wrought-Iron Unclimbable Gate.—This gate (Fig. 61) is intended for situations exposed to trespassers. It is constructed of flat iron uprights pointed at top, riveted to angle-iron frame-work, and placed 2½ inches apart in

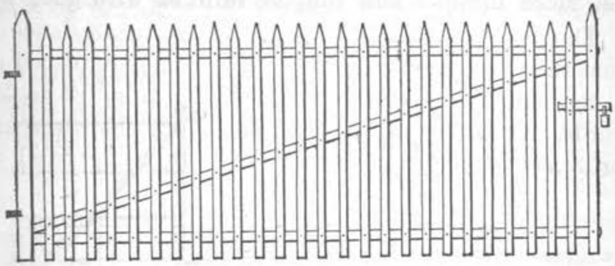


Fig. 61.

the clear. A capital gate of the same pattern is made out of wooden spars.

Wire Gates.—Although plain wire is an unsuitable material for the construction of field gates, being too light to bear the pressure of animals against it, this

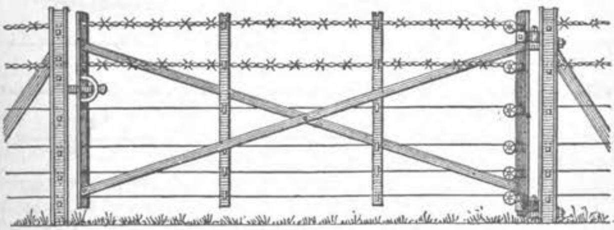


Fig. 62.

objection is entirely removed when barb wire is employed in the gate, if only for the top bars, as no animals will then push against it. Fig. 62 shows a useful gate of this kind, in the line of a barb wire fence

The gate is hung upon ordinary iron straining-posts, and the heel of the gate, which is of angle-iron, is fitted with winding-brackets for tightening the wire bars.

A much cheaper and simpler form of wire gate is

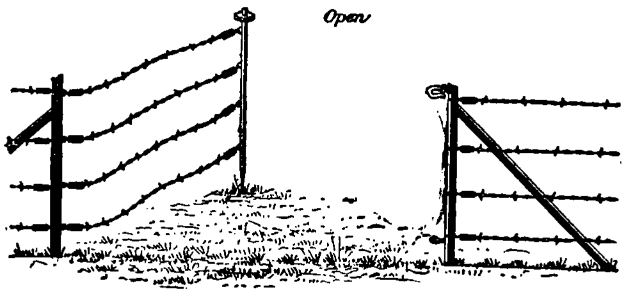


Fig. 63.

shown in figs. 63 and 64, in the former of which the gate is open and in the latter it is shut.

A Sliding Gate.—Gates of this class (Fig. 65) are sometimes used in the line of a paling or wire fence.

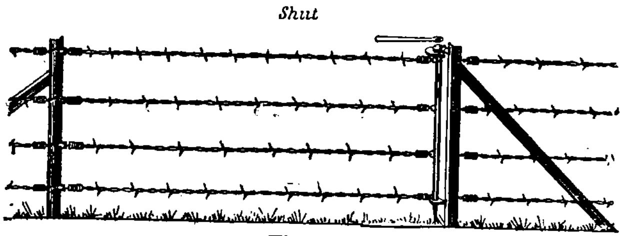


Fig. 64.

They have nothing to recommend them, however, but cheapness, there being no posts and hinges required, as in the hanging gate. The left half of the gate slides backwards between two common fence-posts, which are attached by as many horizontal spars as there are bars in the gate, and the other end of the gate slides two or more of its bars into iron holdfasts, or the ends of all the bars may slip between the horizontal spars

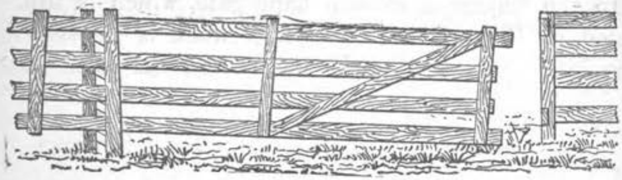


Fig. 65.

attaching two fence-posts, as at the left of the gate. These gates are not so readily opened and shut as a good swing-gate, and this is a great objection when there is much traffic at the gateway.

Fig. 66.

Hand or Bridle Gates.—For bridle-roads and pathways small hand-gates of wood or wrought-iron are a great economy in place of the large field gates, and much more convenient. The wicket is equally adapted as a side gate to field gate, or for standing alone, the posts forming terminals in a line of fence, as in Fig. 66. A wrought-iron wicket of this kind costs from 15*s.* to 17*s.* 6*d.* without the pillars.

In the American wooden hand-gate, which is illustrated in Fig. 67, no blacksmith work is necessary. The hinge-post is 9 or 10 inches and the latch-post

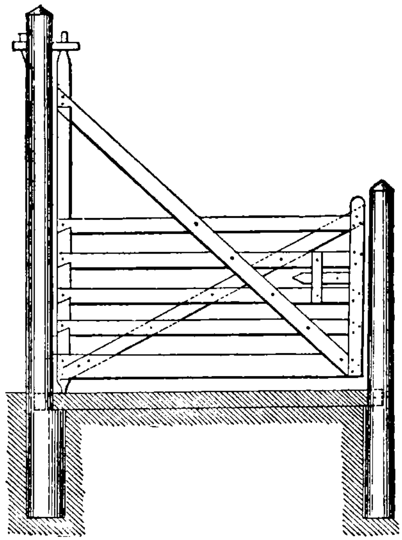


Fig. 67.

8 inches in diameter, both being sunk 3 or 4 feet in the ground. A strong wooden sill is inserted at the ground-level, tenoned into posts and primed. This sill serves to strengthen the posts and to keep them in position. The bars and braces are dovetailed into the uprights. The piece at top, acting as a hinge, should be 3 inches thick, with a hole in it for the end of the heel to pass through. A hole is made in the sill for the bottom of

the heel to work in. The long hinge-post would be objectionable in a line of paling or wire fencing, but it is easily shortened, and the mode of hanging this gate is extremely simple and effective.

In hunting districts a few of these bridle-gates, judiciously disposed in the lines of fencing, and out of the lines of pathways and bridle-roads, will often prevent much injury and damage to the fences. In situations where no pathway leads to them the gates should invariably be painted a different colour from the fence, a

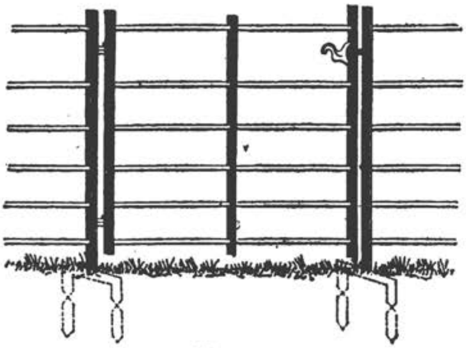


Fig. 68.

gate painted white being the most distinguishable at a distance.

Gate for Hurdle Fences.—These wickets are adapted to meet the demand for a cheap and simple hand-gate to hang between hurdles. They can be hung either to the sides of the hurdles or to standards specially provided for that purpose. A wrought-iron wicket similar to that shown in Fig. 68, and to match hurdles up to 4 feet high, costs 14*s.* or 15*s.*

When a footpath passes through a folded field, and no such gate as the above is available, an easy passage is formed by placing three hurdles in the form of a cage-gate or bow-wicket, Fig. 69; that is, a movable one *c* swings on the stake *b* between the fork of two others

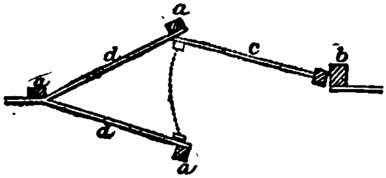


Fig. 69.

set to the stakes *a a*, so as to form an acute angle. This prevents passengers breaking or displacing hurdles by climbing over them or leaving them open.

CHAPTER XV.

WICKETS AND STILES

MANY farms are intersected by public footpaths, which are often a great annoyance to the farmer on account of the fences being broken down or gates left open, and the livestock allowed to trespass amongst the growing crops.

Wickets and stiles are contrivances for such situations in order to allow men to pass over or through fences, while the passage excludes sheep, horses, or cattle. The wicket or turn-about is simply a zigzag or bow passage in the fence, and for temporary use may be formed of stakes and hurdles or posts and rails; but for a permanent passage, such as a public footpath, a well-constructed wrought-iron wicket will be cheapest in the end. There are many kinds of stiles adapted to different kinds of fences. In a dyke or stone wall three or four long stones placed in the height of the fence, and projecting at both sides of the dyke, serve the purpose of steps, by which the passenger ascends to the top and descends again on the other side. Sometimes a strong wooden ladder is fixed at either side of the wall. In a post-and-rail or wire fence, properly constructed fence-steps should be provided, either of the platform or step-ladder kind.

Bow Wickets.—The design of the bow wicket is to provide a gate that will be always shut and yet always open. For footpath gates these are superior to every other kind, as they are not apt to get out of repair from

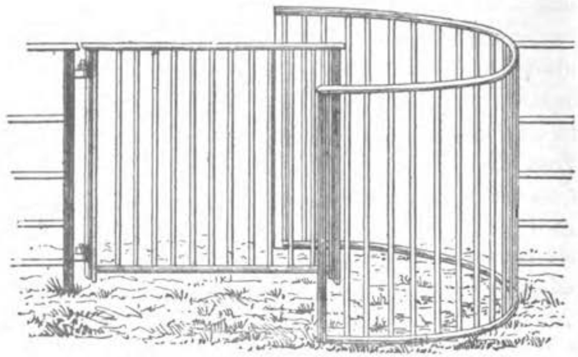


Fig. 70.

constant opening and shutting, having no latch, and are quite secure against livestock. Where there is much

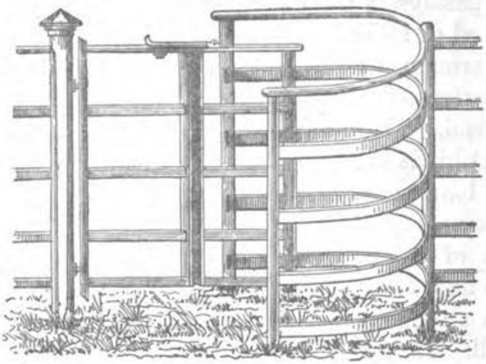


Fig. 71.

traffic they save the farmer from a great deal of annoyance, and even damage, by its being impossible to leave them open. They may be fixed alongside large gates, or in lines of continuous fencing, and look well wherever placed.

A wrought-iron bow wicket is represented in Fig. 70, made with the bars vertical, and placed in the line of an iron fence. The person who wishes to pass this wicket steps into the bow, swings the gate to the front, and passes through to the rear, without the trouble of latching or unlatching, and no quadruped can follow.

Fig. 71 has the bars horizontal, and is hung on a cast-iron pillar. This wicket is also made to fold and

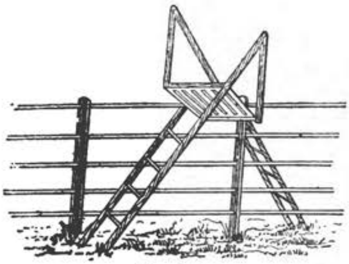


Fig. 72.

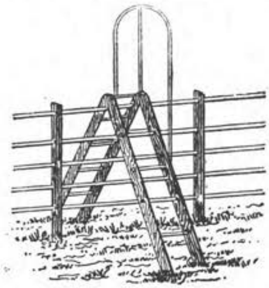


Fig. 73.

open when required, to allow a wheelbarrow or animals to pass through. The prices vary from 35*s.* to 40*s.* and upwards.

In temporary or movable fences, the cage-gate or bow-wicket described at page 114 may be adopted.

Fence-Steps or Stiles.—Step-ladders or stiles, similar to those represented in Figs. 72 and 73, are very generally used in connection with iron or wire fencing. They allow persons to get over the fence easily without injuring the bars or wires. The prices vary from 15*s.* to 30*s.* for wrought-iron steps, according to height and construction.

In a dyke or wall fence, stone steps built into the wall on both sides are most convenient. In a hedge fence, however, the bow-wicket, or an opening stile, will be more suitable.

Opening Stiles.—Several ingenious contrivances are in use for avoiding the climbing necessary in the old-fashioned stiles. Fig. 74 represents an opening stile, of

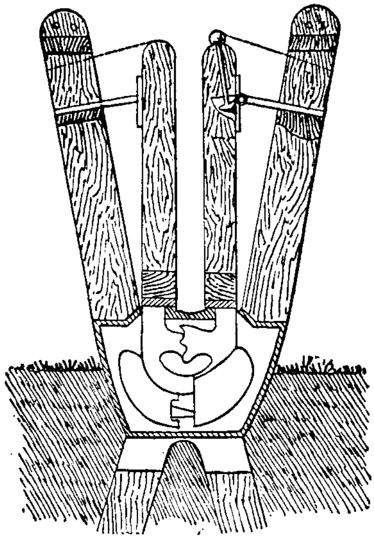


Fig. 74.

which there are several in the grounds at the Royal Agricultural College. It is the patented invention of Messrs Hill and Smith.

Fig. 75 shows another opening stile between two terminal posts in a line of iron bar fencing. This stile is by Messrs. F. Morton and Co.

The stile is made to open as follows. By raising the small knob *b*, the two central posts are readily pressed aside, as shown by the dotted lines, allowing a free open space for passing through. On releasing the pressure these posts fall to again by their own weight, and are self-locking, thus rendering the stile secure against stock.

The stile is constructed for fixing either independent of a line of fence, or for intersecting a line of fence, in which position the two outside posts take the place of

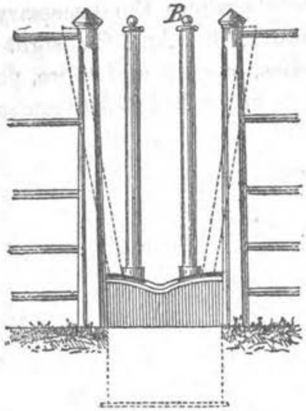


Fig. 75.

terminal posts for attaching the lines of wire, whereby a substantial saving in cost is effected in comparison with the expense of separate gate or terminal posts which would otherwise be required to admit of a gate being inserted or other opening made in the line of fence.

The stile is also arranged when required for fixing at one of the extreme ends of a line of fence, the wires being attached to one of the outside posts, which is fitted with an additional stay.

There are many other kinds of wickets and stiles to be met with, but the foregoing include all those now commonly erected, and none of the others call for any special notice or description.

The lever-bar stile is an example of the latter class. It is, however, a very clumsy contrivance, and is well superseded.

Any kind of gate, wicket, or stile is, at the same time, preferable to a broken-down fence, or a gap-passage, which too frequently appears, even in the best of fences, at points where the necessary gate or stile has not been provided. And the sight of such gaps stopped by hurdles, or here and there, perchance, with an old harrow, is not calculated to encourage the idea of careful and tidy farming.

INDEX.

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THE END.

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SCOTT'S FARM ENGINEERING TEXT-BOOKS

IV.

FARM BUILDINGS

A

PRACTICAL TREATISE

ON THE

BUILDINGS NECESSARY FOR VARIOUS KINDS OF FARMS;
THEIR ARRANGEMENT AND CONSTRUCTION.
WITH PLANS AND ESTIMATES

PREFACE.

WHEN, at the suggestion and request of the publishers of WEALE'S RUDIMENTARY SERIES, the preparation of the present volumes on Farm Engineering was undertaken, it was thought that Mr. Andrews' work on "Agricultural Engineering"—dealing with buildings, barn implements, and field implements, and published in this series thirty years ago—would require to be only partly rewritten to make up this and the two succeeding volumes of the present series of FARM ENGINEERING TEXT-BOOKS. It was soon found, however, that the task of adapting that once valuable work to the wants of modern agriculture involved something more than the preparation of a new edition. Although Mr. Andrews' volumes were amply illustrated, and his plans and designs of farm buildings were well ahead of the times in 1852, not one of the old blocks has been deemed suitable for reproduction in the present volume, and only two or three pages of the original text have been allowed to stand. Practically, therefore, the present is a new work.

In preparing it the aim has been to produce a book which will be serviceable to agriculturists and agricultural students rather than to professional architects and builders, to the latter of whom, no doubt, the work must appear incomplete and faulty. It is not, however, recommended to agriculturists to become their own architects and builders; therefore to those professionals the elaboration of many technical details which are here purposely omitted or curtailed is left.

The current talk now, as when Andrews wrote, is of antiquated farm buildings, unfit for their purpose, and of insufficient accommodation for live-stock. That deficiencies exist in these respects, though more in some districts than in others, is generally admitted. And no farmer now-a-days needs to be told that animals exposed to cold eat more and thrive worse than if better housed and kept warmer: in other words, that shelter and warmth economise food, and are equivalent to an actual shortening of winter.

But, while the accommodation for stock is admittedly inadequate, it is notorious that, even in many such cases, there has already been incurred a building outlay of from £5 to £10 an acre. Now this represents 5s. to 10s. per acre of rent-charge, and under the present conditions of British agriculture few, if any, farms in the country will support the expenditure.

If, then, increased building accommodation and improved buildings are to be provided, the solution of the difficulty would appear to lie in a better arrangement of buildings and in the adoption of cheaper methods and materials of construction.

The larger choice of building materials now available is a great help towards cheaper construction. Instead of walls and pillars being restricted to stone, brick, or woodwork, other materials such as iron and concrete are now, in many cases, found admirable substitutes, alike in point of fitness, durability, and economy; and the costly and cumbersome roofing tiles, slates, and shingles are now often advantageously superseded by the cheaper and lighter covering of galvanised corrugated sheets, asphalte roofing-felt, rubber roofing, or even the Willesden roofing-paper. And the really great saving in the use of these materials is not so much in their greater cheapness as in their lightness of weight, thus requiring so much less roof-framing, both in weight and quantity.

The requirements as to farm buildings are also very different to-day from what they were only a few years ago. These new requirements have arisen from improvements in farm machinery and in preparing food for stock, from altered systems of husbandry, and the larger numbers of stock fed; these and other influences all tending to necessitate more or less change in building-plans and arrangements.

In many districts the sheaf-barn and threshing-barn is falling into disuse, even when completely fitted with threshing apparatus, it being, as a rule, found advantageous to thresh in the field or direct from the stack, with a portable engine and threshing-machine. On the other hand, more attention is being paid to the construction of sheds for securing hay and grain crops, and to silos for preserving green fodder. Another modern necessity is the provision of larger accommodation and better arrangements for preparing and mixing food for cattle. The substitution of covered for open yards also progresses, surely if slowly. And in the changes which are going on, matters affecting the ventilation, lighting, paving, and draining of farm buildings are meeting with the full share of attention which they deserve.

Of farmhouses there is nothing particular to note. Underground stories—except for cool cellarage—and high upper stories are, however, to be avoided in such buildings. These are necessary evils in crowded cities, but are inexcusable in country houses.

The condition of farm-cottages has improved wonderfully of late years, especially on the larger estates, both in England and in Scotland, and that not merely in the matter of accommodation, but also in their sanitary surroundings. Still, in neither of these respects are workmen's cottages in the country all that could be desired. Hence, diphtheria and typhoid fever are still too often harboured amid scenes where they really ought never to exist.

CONTENTS.

LIST OF ILLUSTRATIONS.

FARM BUILDINGS.

CHAPTER I.

HOMESTEAD OR STEADING.

THE various buildings necessary for the occupation and proper working of a farm are collectively known in England as the Homestead, and in Scotland as the Onstead or Steading. Throughout this book we shall use the word Homestead, so that there may be no confusion of terms.

Accommodation necessary.—The usual farm buildings include accommodation for the farmer and his family, for the labourers employed on the land, for the various kinds of live-stock, for manipulating grain-crops, for storing, preparing, and mixing food for cattle, and for implements and machinery of all kinds, &c.

The requirements in these respects are very different to-day from what they were a few years ago, the improvements in farm machinery and in preparing food for stock, and also the greater numbers of stock fed, having necessitated a complete change in the plans and arrangement of farm buildings.

The accommodation necessary varies in size and arrangement according to the extent of the farm, the nature of the principal crops, and the system of management pursued. The same farm which under one system maintains a certain number of sheep and cattle, and requires the labour of so many horses, may, perhaps, under a different system of husbandry, support two or three times the quantity of stock, and increase the demand proportionately for horse-labour.

Each system of husbandry, too, will give prominence to certain departments of the homestead. Thus in a dairy farm, the cow-house and the dairy offices are the chief feature. On a fattening farm, prominence must be given to boxes and covered yards, and to the arrangements for preparing food. On a mixed farm, which generally partakes of all systems, the buildings must be more numerous, and suited in some respects to all purposes.

The buildings and offices necessary for a perfect homestead on a mixed husbandry farm, will consist of—

Farmhouse
Cottages
Corn-barn
Straw-barn
Granary
Chaff-room
Pulping-room
Mill-room
Mixing-floor
Boiling-house
Hay and grain sheds
Silos
Implement-sheds
Cart-sheds
Tool-house
Manure-house
Root-stores
Potato-house
Cow-houses
Calf-pens
Stalls for cattle
Boxes for cattle
Covered yards
Sheds with open yards
Piggeries
Stables
Sheep-sheds
Poultry-house
Dairy
Smith's and carpenter's shop
Mess-room
Engine-house
Wool-store
Slaughterhouse.

We may classify farms under the respective heads of arable, stock, and dairy, and as many sub-divisions as we please. But sub-divisions are not as a rule sharply distinguished from each other, and merely indicate the prevailing features of the farm or the district, such features being generally controlled by circumstances of soil, situation, and climate.

Thus, in a corn farm, a certain proportion of stock is fattened and dairy produce is prepared, although its staple may be grain. The arable stock farm is principally devoted to the rearing and fattening of cattle for the fat markets, and crops and field operations are all directed with a view to that object. In the case of a dairy farm, the ultimate object of the farmer is the obtaining of milk for sale or for the manufacture of butter and cheese, and stock is selected and crops grown suitable for such objects.

Site of the Homestead.—As the health of the live-stock is of supreme importance, farm buildings ought to be placed in situations securing, as far as possible, abundant water-supply, good drainage, freedom from damp, and a sheltered yet airy situation.

It is needless to add that the homestead should be as near the centre of the farm as possible, and that the buildings should abut upon a hard road. Scattered buildings are very objectionable; for although field-barns and yards economise cartage of both crop and manure, they occasion great loss of time in attending to stock, and the stock in the outlying yards can never be so much under the master's eye as is desirable. The best arrangement for outlying fields beyond reach of the dung-cart is not outlying barn-yards, but sheep-folding and green manuring.

The best aspect for stock is south-east by south.

Arrangement of Farm Buildings.—A great deal of labour is saved by an economical arrangement of the various compartments of a building. The various parts should be so compacted that operations dependent on each other, or following in consecutive order, should be performed in immediate proximity; and the saving of all unnecessary labour, as well as the prompt and rapid execution of work, ought always to be kept prominently in view.

The position of the barn, the food-stores, and mixing-floor, will generally be found the key to the whole range of farm buildings, as most of the labour at the homestead is connected with these departments.

It is usually found that farm buildings of moderate extent come together most conveniently in the form of three sides of a square or parallelogram. The space lying between the projecting sides is either roofed over or left as an open court.

Advantages of Covered Yards.—It goes without saying that there is no homestead equal to a covered homestead. Any improvement in shelter for stock is equivalent to an actual shortening of winter. The average temperature of the bodies of our cattle is about 100°, or 40° higher than the ordinary temperature of the atmosphere. Hence there must be some provision in the animal body to sustain the heat, which is absolutely necessary for the performance of its functions. The air being so much colder than the body, must constantly draw from its heat and tend to lower its temperature. We all know that an animal exposed to more cold will eat more, and one better housed and warmer kept will eat less. The explanation is that warmth is an equivalent for food, and that, therefore, food may be economised by protecting cattle from cold. Too much stress cannot be put upon this point, and it does not apply merely to pure-bred stock, for in all cases it is absolute economy of food. It applies also to every age of stock. There is no fear of young animals growing up tender in a covered yard, provided it is roomy and well ventilated. The ventilation, however, should come from above the animals; there must be no draughts in a covered yard. The better manufacture and preservation of manure under cover is another important consideration; but this will be found more particularly noticed on pages 78 and 117.

Outlay on Farm Buildings.—It would not be very satisfactory, perhaps, to attempt to lay down any rule as to the proportion of capital per acre which it is necessary to invest in buildings on any particular class of farm. The class of building, the material used, local circumstances, as well as the extent of the farm and the value of the land, all tend to disturb calculation.

Mr. Denton tells us in "The Farm Homesteads of England," that assuming everything is substantially done, farms of 1,000 acs. and upwards, of tillage and mixed husbandry, will require an outlay in house and homestead of £4,000 to £5,000, or £4 10s. per acre; that farms of between 500 and 1,000 acs. of tillage and mixed husbandry, will require an oulay of £2,500 to £4,000, or £6 per acre; and that farms of between 200 and 500 acs. of mixed or dairy husbandry will require an outlay of £1,500 to £3,000, or £7 per acre. In many cases, it is added, these rates are exceeded, and £10 an acre is expended in buildings.

There are many instances within our own knowledge and experience where the outlay on buildings has ranged from £5 to £10 per acre. That represents 5s. to 10s. per acre of additional rent-charge at 5 per cent. Under the present circumstances of agriculture, however, no land will support that outlay on buildings. At the same time, improved buildings and increased building accommodation is on numerous farms urgently needed. The solution of the difficulty therefore seems to lie in a more economical arrangement of the buildings, and in the discovery of cheaper material and methods of construction.

It appears to be tolerably well agreed upon amongst agriculturists and architects that at the present time a substantial homestead—walls, roofs, and fittings, all included—cannot be built for much less than £10, while the cost often amounts to £15, a square. Hay-sheds, and the like, can, however, be completed for something like £3 to £5 a square.

Who bears the Cost?—The landlord is supposed to make the needful outlay in buildings, but in reality he seldom does so. When the outlay is made a rent-charge to be paid by the tenant, it is assumed to be paid by the land. The land, however, is frequently over-rented before the outlay is made, and practically in such cases to charge the tenant interest on the expenditure is to saddle him with the entire outlay. A landlord of our acquaintance recently borrowed money under the Land Improvement Act to build a pair of cottages on one of his farms where they were much wanted; and because the tenant of the said farm refused to pay a full annual rent for the new cottages, *in addition to* 6 *per cent. on outlay* to reimburse the borrowed money, he actually did not get the use of the cottages after all.

And, on many estates—many of the largest estates in the country—it is a very common practice for the tenant to be required to draw all the materials for new buildings at his own cost. He has to do this very often, and in addition pay the rent-charge to redeem the actual expenditure. Now the horses and regular staff on a farm are generally just sufficient for the regular tillage operations of the farm, and if this haulage of material is undertaken, that work must suffer. Moreover the haulage of materials is a very important item in the cost of a building, and it is only reasonable that if a tenant does this part of the work that he should be paid for it at its value. He might then be able to afford the payment of interest on the building outlay, but he cannot also be expected to undertake the haulage of materials at his own cost.

CHAPTER II.

MATERIALS AND CONSTRUCTION.

Materials.—The question of building materials deserves to be considered in regard to many points which the limits of this work will barely admit of being enumerated. They should be durable of their kind, and at the same time suitable in character and strength for the class of building about to be erected. In consulting cost, materials from a distance will often be cheaper than any substitute that may be obtainable on the spot. It is essential, however, to ascertain the various materials that can be obtained in the district, their quality, fitness, and the distance and convenience of carriage. Where these conditions favour their employment, local materials, as a rule, ought to be preferred, as they generally harmonise best with the characteristics of the district, and are probably best understood by the workmen who are available in constructing the building. The materials used and the method of construction must ever, to a certain extent, depend on the locality, though the continued discovery or invention of new materials, as well as the increasing facility and cheapness of transport, renders this less a necessity than at former times.

Foundations.—All walls should be founded at a depth of not less than 18 in. below the natural surface of the ground. In good buildings, or where the substratum is not of the best character, the foundations of walls should be laid on concrete of a minimum depth of 1 ft., and minimum width of 2 ft. And it is essential for dryness, when walls communicate directly with the earth, that there should be a "damp-course," at least 6 in. above the level of the surrounding ground when finished; the "damp-course" to consist of asphalte, or tar and sand, slate, or other impervious materials.

Walls.—The materials used in the construction of walls are stone, bricks, wood, iron, cement, artificial stone, mortar, and clay.

Masonry.—It is often a question whether the walls of the several buildings be of one or other, or of several of these materials. For permanent buildings stone walls are to be preferred, if this material can be obtained at as low a cost relatively as the others. When the walls are to be of stone, shall granite, or whinstone, or sandstone, or limestone be preferred? Supposing all of these are equally attainable, what consideration should determine a choice of one of them rather than of another? How far do they differ in hardness, compactness, durability, permeability to moisture, and indifference in general to the action of rain, wind, or weather, and to what extent are some of them more quickly, cheaply, and neatly quarried than others?

Outside walls, when of stone, are generally constructed a minimum thickness of 20 in., and inside walls of not less than 15 or 18 in.

Brickwork.—Outside walls, when of brick, should be of a minimum thickness of 9 in. For low buildings, the thickness usually adopted is 9 or 14 in., and for double-floored buildings 14 or 18 in. A 9-in. wall for low buildings, strengthened by 14-in. piers, 10 ft. apart, and on which the trusses of the roof rest, is practically as strong and serviceable as a 14-in. wall.

A rod of brick-work is 16 ft. 6 in. × 16 ft. 6 in. × 1½ bricks, or 13½ in. thick.
" equals 272¼ sup. feet × 1½ bricks thick; or 306¼ cubic feet; or 11⅓ cubic yards.
" requires on an average 4,350 stock bricks.
One cubic yard of brickwork requires 384 bricks, and from ¼ to ⅓ cubic yard of mortar.
" " in mortar weighs 27 cwt., in cement 29 cwt.

An average brick weighs 6½ lbs. Ordinary bricks in cement crush with 520 lbs. per square in.; the cement will crush with from 700 lbs. to 900 lbs. per square in., and mortar with from 400 lbs. to 600 lbs. per square in.

To execute plain brickwork for £13 per rod, the bricks must not cost more than £2 per 1,000, delivered.

Mortar.—The mortar used in masonry or brickwork should be mixed in the proportion of nearly 1 part of lime to 2½ parts of sand. 1 cubic yd. or load of mortar requires 12½ cubic ft. of lime and 27 cubic ft. of sand, or 9 bush. of lime and 1 load of sand. These proportions, however, only apply to stone-lime. When chalk-lime is used the proportions are 3½ parts of lime to 6½ parts of sand, or nearly 2 parts of sand to 1 part of lime. The sand should be clean, sharp, and coarse-grained. It is said that walls cemented by mortar containing sea-sand are always wet, and tha t if we wish dry walls we should select pit-sand.

Concrete Walls.—In many districts, and especially where building-stone or bricks are scarce, and where skilled labour is difficult to get, concrete is now largely employed as a substitute for masonry or brickwork. Concrete can be made at little expense, and will form hard walls equal to stone. In certain situations, therefore, it will be found particularly adapted for the erection of farm homesteads or cottages.

The ingredients used in preparing the concrete are cement and either gravel, broken stones, bricks, shingle, &c.; and the proportions should be 1 part of cement to 6 parts of the broken stones or gravel. Portland cement should only be used stale, and after it has been exposed to the air for two or three months, and turned over more than once in that time. The materials are mixed on a wooden boarding or floor, and the mixture is carried or hoisted in pails or buckets up the scaffolding and poured into the moulds, which are simply wooden boards about 18 in. deep, set to the required thickness of the walls all round the building. The whole building, of whatever extent, may thus, by employing a sufficient number of labourers, be carried up 18 in. daily; and as the concrete sets quite hard during one night, the mould-boards can be raised the next morning and a new addition made to the walls. In calculating the time it will require to carry up the walls of a building, it is therefore only necessary to allow 18 in. in height daily.

In many districts a plentiful supply of a good material for making concrete is ready at hand in the form of shingle from the sea-shore. This is mixed with cement in the proportions already mentioned, and in the interior of the walls brickbats are hand-packed and carefully bedded all round in the concrete mixture. The brickbats used (in addition to the concrete as first mixed) may vary from one-half to one-third of the cubic contents of the walls. The bricks, stones, or whatever else is used, should be crushed into pieces not exceeding $\frac{1}{3}$ in. cube. There should be a considerable proportion of smaller material; but anything of the nature of clay, fine sand, loam, mud, or dirt of any kind must be carefully excluded. Clean, coarse sand may be used, but not in too large proportion.

In carrying out the work common labourers can do all the building, with the assistance of a skilled foreman, who should be a carpenter, to make all moulds and see them properly set, and also make provision for the fixing of the timber-work of the buildings. The foreman requires no previous experience in concrete building, because the concrete will mould to any form or shape. All lintels, sills, steps, projections, cornices, &c. are formed of concrete, and to any mould. The backs of fireplaces are built of brickwork to the height of the lintel, but the remainder of the flues and the chimney-tops are all constructed in concrete. The method of forming the chimney-flues consists in filling the concrete round an iron tube of a diameter corresponding to the required size of the flue. The tube should be about 2 ft. long, and may be straight or curved, according to the course of the flue. After the concrete has hardened the tube is withdrawn, and as the walls are raised the process is repeated.

As regards the cost of concrete walls, it is estimated at from one-third to one-fourth less than for masonry or brickwork. This is our own experience, and it accords pretty well with the following comparative estimate of the cost of concrete and brickwork by Messrs. Hill and Smith.

CONCRETE.

	s.	d.
1 cub. yd. of clean gravel at	4	0
2⅝ bushels Portland cement at 2s. 6d.	6	7
Labour—Mixing and depositing	2	6
,, Fixing appliances	0	9
Use and depreciation of appliances	0	6
Per cubic yard	14	4

BRICKWORK.

		s.	d.
400 bricks at 40s. per 1,000 delivered		16	0
⅛ yard of lime at 12s.		1	6
¼ yard of sand at 2s.		0	6
Labour		4	0
Per cubic yard	£1	2	0

In all the applications of concrete that we have seen it appears to answer the purpose intended equally as well as stone or brick. A 4½-in. concrete wall is stronger than an ordinary brick wall of the same thickness, and owing to the cement employed in the concrete it is quite impervious to damp, freedom from which is further insured by washing over the exterior of the walls with cement, after which the buildings have a smooth and finished appearance. The concrete also stands vibration remarkably well. Altogether, it is a safe, convenient, economical, and satisfactory substitute for masonry or brickwork.

Timber Frames.—Although timber is less durable than stone, brick, or concrete, it is quite as suitable as any of them for the erection of various kinds of buildings, and there are situations where buildings of all kinds have to be constructed entirely of wood. The wooden framework should be built upon brick or stone and concrete foundations, with damping-course, and the structure of such buildings, for farm purposes or cottages, should be of quartering 4 in. thick, covered outside with weatherboards, shingles, or tiles, and inside with wood or lath-and-plaster.

Roofs.—The roofs of all farm buildings should combine as far as possible strength and durability with economy of cost and the maintenance of an equable temperature.

In the framing of trusses wood and iron are both used, either separately or combined. The latter is used for this purpose with good effect, affording as it does a light internal appearance to the roof, which is very desirable where much space is covered.

Roofing Materials.—The nature of the covering will in a great measure rule the form or strength of the frame-work, and consequently the cost of the whole structure. The materials employed in roofing farm buildings are either slates, tiles, wooden shingles, corrugated iron, galvanized iron, asphalte roofing-felt, or roofing-paper. There are special good qualities in each of them, and local considerations most frequently determine which of them shall be used. Roofs, of whatever materials, must be watertight.

Roofing slates are economical, because while they are very durable they admit of a light and low-pitched roof. Good slates do not absorb moisture, and are practically as lasting as iron or lead. Where slates are cheap, therefore, no better covering is possible, unless flat roofs are wanted, when lead or cement would be preferable.

Where slates are used they should always be nailed on 1-in. rough boarding or sarking, and never on laths, even in the case of less important buildings. Slates are quick conductors of heat and cold, so that unless they are laid on boards the temperature of the building will be very irregular; and the difference in cost is immaterial, because a lighter and cheaper slate can be used on boarding than will suffice on laths.

The slates should be laid with a lap of not less than 2 in. for the smaller sizes, and 2½ to 3 in. lap in the case of the larger sizes; and every slate should be double nailed, with nails of copper, zinc, or galvanized iron.

Gutters between roof should be laid with lead, 7 lbs. to the foot.

The ridges of slate roofs should be either covered with a zinc crest or with lead 6 lbs. to the foot.

Tiles, plain and pantiles, have an advantage over slates in keeping the buildings so covered warmer in winter and cooler in summer; but on the whole they are a much less satisfactory covering than slates. A tile roof is rarely watertight, and, as the tiles are comparatively heavier than slates, and are extremely absorbent of moisture, they require heavier timbers and a higher pitch of roof. The tiles are also far less durable than slates. When plain tiles are used it is customary to put a little hay or straw between them and the laths.

Shingles are pieces of split or sawn wood—oak or other hard wood—cut to the size and form of slates. They require to be laid on weather-boarding, the same as slates. They are a very suitable covering for wooden buildings, and in such cases are often used for covering the outside walls as well as the roofs.

Galvanized Corrugated Roofing Sheets are rapidly superseding the use of slates, tiles, or shingles. They are cheap, strong, portable, fireproof, very durable, easily erected or taken down, and require but little framework. For covering hay-sheds, cart-sheds, piggeries, and the like buildings, their value has long been generally admitted; but they are equally well suited for covering cattle-yards, cow-houses, stables, barns, and granaries, when sound quality of iron and proper galvanizing are secured

These sheets can be applied both to iron and timber-framed roofs, whether of the curved, pitched, or lean-to kind.

One of the simplest forms of roof is the galvanized self-supporting roof illustrated in Fig. 1. The uprights or eaves-beams may either be of iron or timber; and in the roof itself all the support needed is a crown-bar of angle-iron, running from end to end of the roof, to which the sheets are secured by bolts and nuts, with tie-rods generally at each end of the span.

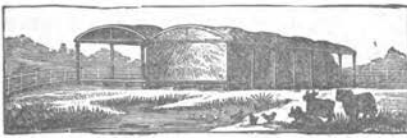


Fig. 1.

The galvanized trussed roof is, however, more suitable for wide spans. As the self-supporting roofs are constructed without iron principals, their strength depends chiefly upon the sheets themselves. The principle is a most valuable one, but the sheets must necessarily advance in thickness, and other details in strength, as the span of the roof is increased. In this way self-supporting roofs are applied to spans of a considerable width; but it is self-evident that a roof constructed with iron principals must be stronger and more stable than one without principals; and only the increased cost hitherto necessary has prevented the former arrangement being generally preferred.

The difficulty has thus been to provide iron principals and purlin-bars in a roof above a certain span in such a form as to secure the strength of the trussed principle, while not exceeding the cost of a self-supporting roof of sufficient strength. This difficulty has been overcome by Messrs. A. & J. Main & Co., in their improved trussed roof, illustrated in Fig. 2, which, when applied to hay-sheds, has the further advantage over other trussed roofs that it can be filled to within a few inches of the ridge, all obstructive tie-rods being dispensed with.

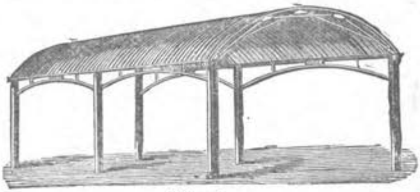


Fig. 2

For spans of 30 ft. and upwards these improved trussed roofs are actually cheaper than a self-supporting one; but below 28 ft. span it is found that the self-supporting roofs have still the advantage in price. On the other hand, these trussed roofs can be applied to spans up to about 50 ft. at a price which could not formerly be attained, and the construction is thus a most important one.

In the application of corrugated iron to timber-framed roofs, the sheets are fixed to the spars or laths. No boarding is required, and, if bolts and nuts are used, the sheets can be fixed by any handy workman with the aid of a hammer, punch, and spanner, without skilled help.

Fig. 3 is a simple arrangement of a lean-to roof, with timber uprights and framing, very suitable for cart, implement, or cattle-sheds, and for many other purposes.

Asphalte Roofing Felt being cheap and easy of application, and requiring but light timbers compared with a roof of slates or tiles, is well adapted for covering farm buildings. Under slates, tiles, and galvanized iron, being non-conducting, it is good for keeping buildings cool in summer and warm in winter.

On ordinary roofs the felt should be laid lengthwise from gable to gable, overlapping each breadth about 2 in., and closely nailed with flat-headed tacks. On bowstring roofs it may be laid across from eaves to

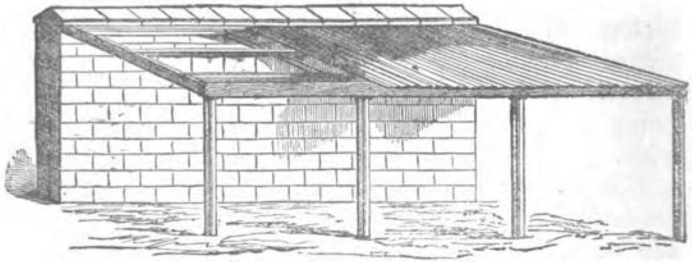


Fig. 3.

eaves, carefully tarred underneath the overlap, and closely nailed. All felted roofs should be coated with tar or felt varnish when completed. This should be renewed occasionally, always choosing fine dry weather.

The felt is made in rolls 32 in. wide, and when of good quality is uniformly even and pliable, and does not adhere, tear, or crack in unrolling. In cold weather it should be kept in a warm room before being unrolled. The felt costs from 4½d. to 5½d. per lineal yard. The number of lineal yards required is most readily found by adding one-fifth to the number of square yards to be covered.

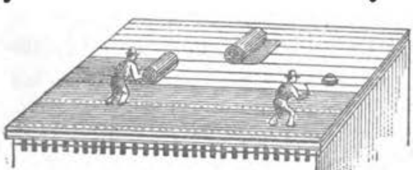


Fig. 4.

Rubber Roofing is extensively used in America for laying over rough boards, as in Fig. 4. It costs about 12s. 6d. per square, 10 × 10 ft., and will last a lifetime on steep or flat roofs.

Willesden Roofing Paper has of late been attracting considerable attention as a covering for sheds and other buildings. It has much the appearance of ordinary brown paper cardboard, coated both sides with oil and varnish, and looks as if it would last quite as well as felt or rubber roofing. Writing to the *North British Agriculturist* in April last, Mr. George Waldegrave Leslie says: "At the Reading Show of the Royal Agricultural Society last year, Cameron, M.P., of Lochiel, and myself observed a building roofed with a material which seemed to be good and efficient. It was the Willesden Paper Roofing.

"I may mention that the buildings of the Fisheries Exhibition at South Kensington will this year be entirely roofed with this material.

"Mr. Cameron tells me that he has tried it in Inverness-shire with satisfactory success; and I can add that having covered in a large homestead in October last with this material, I have so far every reason to be satisfied with it. It has successfully stood the heavy snowstorms of December, 1882, and of January of this year, and all the severe frosts of this protracted winter; and some six cot-houses (cottages) on the Rothes estate roofed with it have also proved warm and comfortable to the occupiers.

"The really great saving is, I think, in its lightness of weight, and thus requiring so much less timber both in weight and quantity. I reckon that the saving of timber in the roofing of my covered court amounts to considerably more than £100.

"I think that this patent roofing may safely be tried by anyone desiring a less costly roofing than slates, tiles, or corrugated iron."

The Pitch or Angle for Roofs.—Common tiles ought not to be laid lower than an angle of 45°, but are better at a higher pitch, which the ordinary stone slate absolutely demands.

The thin flagstone slates of Yorkshire and Lancashire may be laid somewhat lower than 45°, but are far better higher. The Westmoreland slates may be laid as low as one-third of the span, and the Welsh slate at one-fourth, but both are better for a higher pitch.

Felt, rubber, and Willesden paper may all be safely laid at about the same pitch as Welsh slate, and they are often laid on flat, or nearly flat, roofs.

Corrugated iron is laid at all angles. Lead, though the best covering for flat roofs, is also a noble covering for a high roof.

In the abstract a high roof is suitable to a climate which is subject to heavy falls of snow, and is, as a general rule, better than a low one; some roofing materials demand, and probably all are better for, a good slope.

Ridges, Eaves, Spouting, &c.—It is essential that all buildings should be spouted, and that the water so collected be carried away to a safe distance from the foundation of the house. This is necessary for the preservation of the buildings, whether dwelling-houses or buildings for live-stock, and for the health and comfort of the occupants. In connection with the farmyard, it is equally necessary for the proper manufacture and preservation of manure. And in the case of many dwellings and homesteads, the rain from the roofs is one of the principal sources of water-supply for drinking, cooking, cleaning and other purposes. In such cases the water collected from the roofs should be taken direct to an underground tank, and there preserved. On high buildings the water from the roof can usually be collected in a cistern on the upper floor, at a height sufficient to ensure a full and constant service to any part of the buildings; the surplus water from this cistern passing on to the larger underground tank, and a windmill or other arrangement being employed to pump the water back to the cistern on the upper floor in dry weather.

The valleys and gutters of all farm building roofs should be of lead weighing not less than 6 lbs. per superficial foot, and not less than 12 in. broad. The ridges should have a 12-in. covering of zinc, Fig. 5, weighing at least 32 oz. per square foot. The whole eaves of the buildings should have 4½-in. water-runs, made with a bead in front (see Fig. 6), of zinc weighing not less than 32 oz. per square foot, and laid in galvanized iron straps, securely nailed to the roof timbers or sarking.

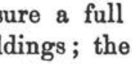


Fig. 5.

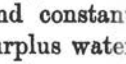


Fig. 6.

Cast-iron fall pipes, 3 in. to 4 in. diam. should be provided at as many points as required, and made to discharge into the storage tanks or drains.

Doors.—Large and heavy doors for barns and sheds should be "constructed to move on rollers instead of hinges, and set in reveals in the wall instead of hanging cutwards, exposed to the action of the wind." They may either be made to move on rollers on a bar fixed above the doors, or on rollers running level with the sills. Of the two plans the former is preferable when the bar on which the rollers pass can be firmly and permanently fixed into the walls, as in the other plan the rollers frequently get clogged.

Ventilators.—No system of ventilation is complete without an inlet for the admission of pure air and an outlet for the escape of the impure. At the same time draughts should be carefully avoided.

In stables and cow-houses the admission of pure

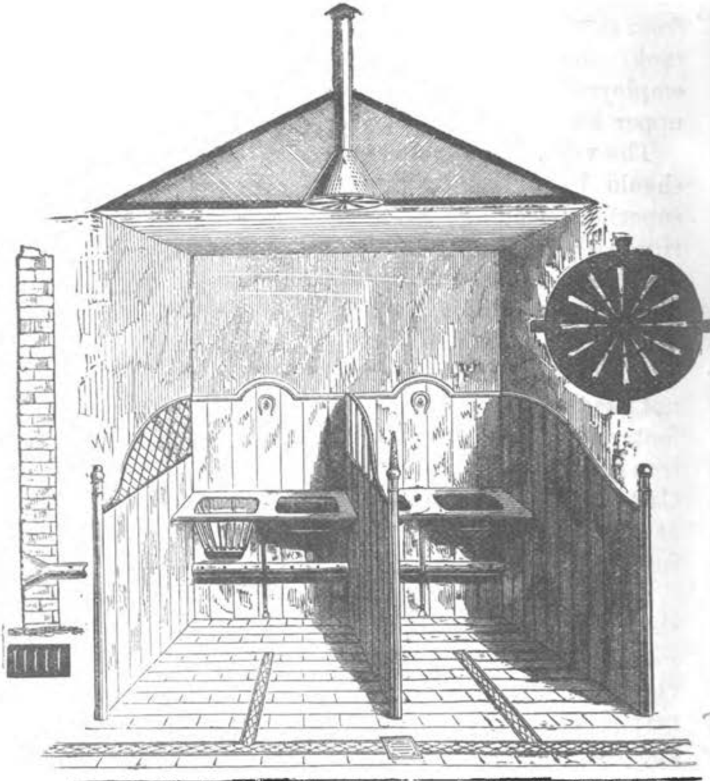


Fig. 7.

fresh air is obtained by various means. Sometimes an iron pipe thinly perforated is run the whole length of the building, under the mangers or against the back wall as may be deemed best, 18 or 20 in. from the ground, the ends being bell-shaped, and attached to sliding gratings outside the walls. Sometimes "air bricks" are built in the walls at the back of the stock nearly on a level with the floor. In other cases vertical tubes are placed against the wall, or against the stall-posts, for admitting fresh air at the roof and carrying it down to the lower part of the building.

The impure air which is exhaled from the animals' lungs ascends to the roof, or will do so if there be means for its escape. In stables with ceiled roofs the escape of impure air is provided for by means of a circular sliding ventilator fixed to the ceiling, as shown in the illustration here given of a stable built and fitted by Messrs. Cottam & Co. The ventilator is in the centre of the stable, and is fitted with rack, pinion, key, and long arm for regulating the size of the openings, having a wrought-iron hopper and pipe passing through the roof, surmounted by a cap or cowl to prevent down currents. Where there is a hayloft over the stable the pipe can be carried through the centre, or in any direction by means of bends, the foul air thereby, in its escape from the stable, not affecting the hay in the loft; and where sleeping-rooms are over the stables it is a most effectual method of keeping them wholesome and fit for habitation.

In cow-houses, feeding-boxes, covered yards and the like buildings, nothing answers better than the louvre ventilator, Fig. 8, fixed on the ridge of the building, for the purpose of withdrawing the foul air. The louvre ventilators are made of wood or iron, and with or without skylights as may be considered necessary.

Raised open-ridge tiles are also employed for ventilating such buildings. When the roof consists of more than two spans, excellent ventilation as well as efficient lighting is obtained by having the central span a foot or two higher than the adjoining ones, and leaving a corresponding break and overlap in the roof the whole length of the building on both sides. We prefer this plan above all others for covered cattle yards, as the animals though under cover then retain a hardy and vigorous constitution.

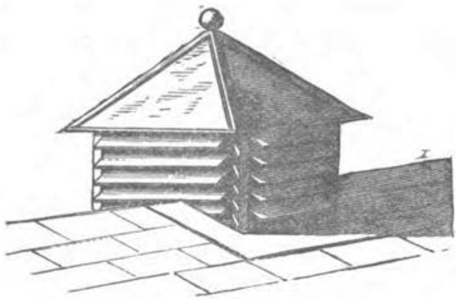


Fig. 8.

Of course in all such buildings there is more or less additional ventilation by the opening of doors and windows.

The ventilation of granaries may be rendered perfect by one or more of the foregoing methods, the essential thing here being to exclude damp while admitting a thorough passage of air.

In iron shedding generally, and especially when used for storing grain, hay, or other produce, ventilation should be carefully attended to. The accompanying illustrations, showing the arrangements introduced by Messrs. A. & J. Main & Co. in their iron shedding,

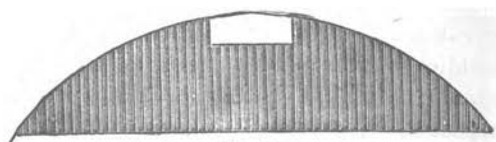


Fig. 9.

are very generally adopted, as they are found effective for their respective uses.

Fig. 9 is merely an opening in the end cleadings, about 18 in. deep, causing a current to pass over the top of the produce stored. For sheds up to about 45 ft. in length this arrangement alone is found sufficient.

Fig. 10 shows an arrangement for having an opening

Fig. 10.

in the roof (generally 2 to 4 ft. wide) covered over by two or three sheets curved to a different radius. This is the simplest ventilation for self-supporting roofs; and one or more such are adopted in sheds 60 ft. long and upwards, according to length.

Fig. 11 is a raised ventilator for roofs, curved or

Fig. 11.

ridge-shaped, having iron principals. The ventilator uprights are secured to the roof principals, and covered over with curved sheets attached to the purlin-bars provided in the ventilator.

Fig. 12 shows a raised ventilator and skylight combined, for roofs similar to foregoing. In this case the ventilator is formed in the same manner as No. 11; but it is made ridge-shaped, and provided with iron

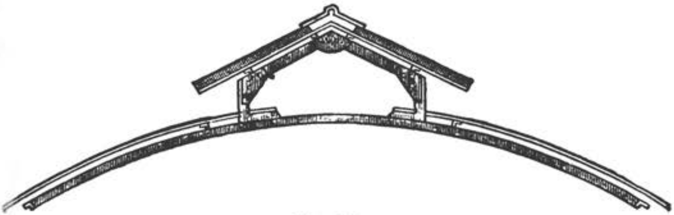


Fig. 12.

astragals for glass, by which light is admitted to the building. A ridge cover is necessary for the apex.

In dwelling-houses the chimney is the natural outlet ventilator, and in old houses where alterations are difficult it should be used as such by an opening directly into the flue from the upper part of the room, properly guarded by a back-draught preventer; while in new houses there should be an opening into the ceiling and thence into the chimney. For inlet there may be entrance flues behind the fireplace, or some of the other modes previously suggested, in addition to doors and windows.

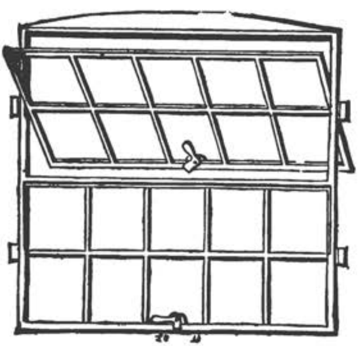


Fig. 13.

Windows.—For stables, cow-houses, granaries, and other farm buildings of the kind, where side-lights are possible, there is nothing to equal the swing-sash window. It may consist of a single-swing sash and frame; or it may be a double-sash window similar to the wrought-iron sash manufactured by Messrs. Cottam & Co., and shown in our illustration (Fig. 13), with one or both sashes made to open as required. These windows are far more efficient ventilators than the "Hit and Miss Shutters" or wooden slides which may often be seen forming the lower sash of windows in old stables, cow-houses, and granaries; and at the same time the buildings are more perfectly lighted by them. A bull's-eye light ventilator (Fig. 14) is often useful in situations where there is little wall space.

Fig. 14.

When buildings are lighted from the roof, thick glass lights without sashes should invariably be used, and as these should be fixtures, ventilation requires to be provided for separately. All covered yards are best lighted from the roof, and, as already mentioned, where the roof is of three or more spans this is well provided without windows or glazed lights of any kind, by raising and overlapping the central span. Indeed buildings for live-stock, stables and cow-houses, &c., are best lighted from the roof when it is possible to do so.

Floors.—In all dwellings the whole area inside the walls should be excavated, or filled, as the case may be, to a level of at least 9 in. below the level of the adjoining ground; and over the surface thus formed should be spread a layer of slag or broken slates at least 7 in. thick, and covered on the top with 2 in. of dry coke ashes. The finished floors in houses should in no case be less than 6 in. higher than the level of the surrounding ground, and all timber floors should have a clear space of 9 in. between the bottom of sleeper joists and the surface of the previously filled in dry materials. Cement floors should be laid with not less than 2 in. in thickness of the cement mixture; and the cement carried 6 in. up the walls by 1½ in. thick, without any break, so as to form a solid skirting. The cement should be laid on a good foundation of broken stones or bricks 3 in. in thickness and broken to pass through a ring 1½ in. in diameter, the space below having been previously filled in with dry materials and well rammed and levelled before receiving the broken stones or bricks. Flagstones and bricks may be laid on a foundation prepared in the same way as for a cement floor.

In stables and loose-boxes there are many objects to be aimed at in selecting the top material. It must be watertight, and non-absorbent; it must be easily cleaned and smooth, but not slippery; and it must be hard, strong, and durable. There is no material which better fulfils these conditions than a good paving brick, or, what is preferred by many, a good blue Staffordshire brick set on edge in cement.

In cow-houses, fatting stalls, and piggeries, also, there is no flooring to equal a good brick pavement.

A wooden floor, whether a plank floor or a wooden pavement, is the very worst for live-stock to stand upon. The wooden pavement lasts well, but, even where wooden blocks cost nothing, it is not to be recommended, inasmuch as it soon becomes saturated with moisture and filth, the odours and vapours from which are unwholesome and injurious. Plank floors are open to the same objection as wooden pavements, and they are not half so durable. A wooden spar-floor is only a degree better, and, except for portable sheep-sheds, or something of that kind, can seldom, if ever, be advantageous.

The bottoms of fatting-boxes and of covered yards are best excavated to a depth of 30 in. below the surrounding floor-level, and then covered with rough concrete or cement. This arrangement is the best for making manure, as all the liquid droppings are retained and absorbed if the littering is carefully attended to.

For barns and granaries on the ground level, asphalte flooring laid on concrete will be found the best means of preserving corn from damp and vermin. The same material, or concrete alone, is also the most suitable for covering the floors of root-houses and of food-preparing and mixing-houses, as also for lining ensilage pits.

Water Supply.—Water should be laid on direct to every stall, box, or covered yard for stock, but there need not necessarily be a separate water-trough in each compartment, as one trough fixed in the partition will serve at least for two divisions. An improved supply and waste-cock for water-troughs has been introduced by the St. Pancras Ironworks Company. It provides a ready and simple means of supplying and emptying the trough through one opening, and avoids all dangerous projections in the manger fittings. An illustration of it is given in Fig. 15.

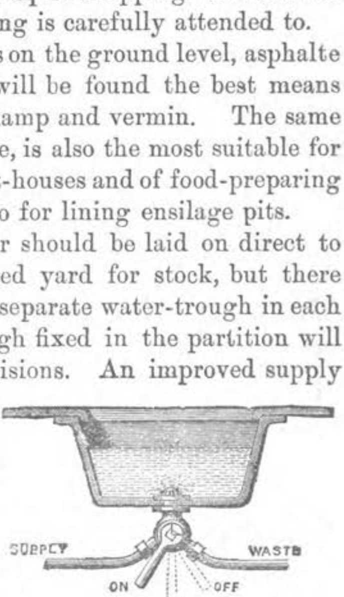


Fig. 15.

Drainage.—Where open yards are the rule, the gutters or drains from the stables, cow-houses, and fatting-stalls should all lead direct into the dry manure pit, or, failing that, into the liquid manure tank, as should also the drainage from the open yards themselves. Where there are covered yards the drainage from stables and cattle-stalls should all be led thither, where it will generally be found advantageous, in order to thoroughly saturate the dry portions of manure or litter in the corners of the yards. If the bottoms of the covered yards and fatting-boxes have been formed in the manner already recommended there will be no drainage from them whatever, and the manure will be considerably improved. Liquid manure-tanks are then unnecessary, as will generally also be dry manure-pits, where the solid manure from the stables and cow-houses, as well as the drainings, can be discharged into the covered yards.

In the drainage of stables very many plans have been

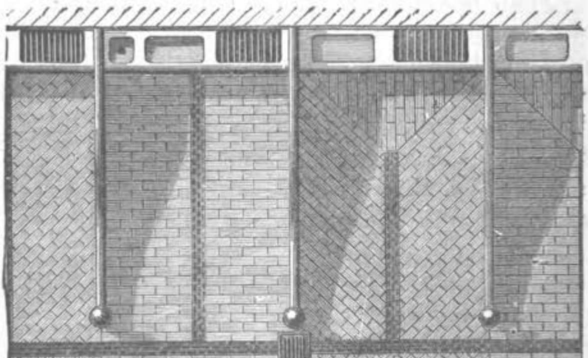


Fig. 16.

adopted. The most improved methods are, however, shown in the annexed plan (Fig. 16), of four stalls in a stable erected and fitted by the St. Pancras Ironworks

Company. A cast-iron gutter with a perforated cover, the latter movable, and laid nearly flush with the bed of the pavement, runs the whole length of the stable, behind the horses. Into this main gutter, which has one or more trapped drain-pots in its length, a gutter leads at right-angles from each of the stalls. In the two stalls on the left it will be noticed that the gutter is carried right up to the wall, so as to receive direct from the water-trough the waste water, which, running down the gutter, carries with it the urine, and tends thus to purify the atmosphere of the stable. In the two stalls on the right the gutter is not carried up to the mangers, the pavement being mitred to the end of each gutter, and laid with proper slopes or falls to insure the thorough drainage of the head end of the stalls.

The system of drainage for loose boxes which is adopted by the St. Pancras Ironworks Company is shown in Fig. 17. A trapped drain-pot is fixed in the centre of the box, and has short lengths of surface-gutter projecting from each of its four sides. There are movable safety covers to each inlet, and the whole is connected with the drain leading to the outer yard. Where water-troughs are used in the manger fittings it is desirable to continue one length of the gutter right up to the wall, to receive the waste water from the trough.

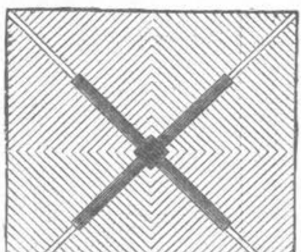


Fig. 17.

Fig. 18 shows the improved drainage and water-

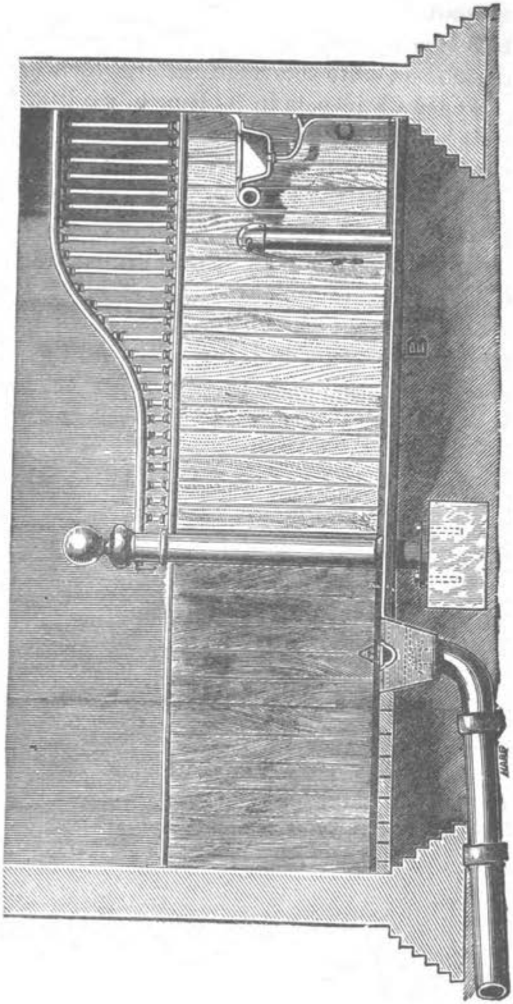


Fig. 18.

supply systems in one of the stables erected by the St. Pancras Ironworks Company. The water-trough of the manger fitting is provided with the improved supply and waste-cock (Fig. 15), attached to a pipe, by which a supply of fresh water is brought in from tank or cistern. By the same cock the waste water is conveyed by the pipe C into the surface-gutter B, and thence with the urine in the gutter into the trapped drain-pot, A. The pot is effectually trapped to prevent any return smell, and is formed to receive the earthenware drain-pipes for finally removing its contents.

If the earthenware drain-pipe is connected with a main sewer, an air-pipe should be attached to it, and carried up by the wall outside the building. This relieves the pressure of sewer-gas, which, when great, sometimes is able to force its way through the water into the stable.

The cow-stalls should be paved so that the cows stand upon a raised floor, with a step of 3 or 4 ins. under their tails, beyond which should be formed a wide, shallow, open gutter, having a slight fall to the drain-pots or the dung-yard, into which it is best that the open gutter should discharge, and which is easily effected where the cow-house wall adjoins the covered yard. This grip or groupe, as it is termed, receives all the cows' droppings, the more solid parts of which may be gathered up, while the liquid portion flows off, and the platform on which the animals stand is kept dry and clean.

CHAPTER III.

EXAMPLE HOMESTEADS.

THE ground plan of a partly covered homestead which was recently erected in Northamptonshire, on a farm of 270 acs., 150 acs. of which are arable, and 120 acr. pasture, is shown in Fig. 19.

This homestead has been referred to and described in the *Agricultural Gazette* in the following terms:—

"It provides stall, box, and yard accommodation for 50 beasts, standing for 9 horses and 4 cows, a calf pen, three pigsties, and 2 loose boxes, with a shelter shed and yard, available either for horses or for young stock, all in easy and direct communication with the cutting and mixing-floors. And there is ample room for housing implements and for storing and dressing corn.

"The special feature in the Homestead is the covered yard, which is provided with ample ventilation and light. It consists of a wide centre span, with lean-to roofs therefrom, the space between the top of the roof to the eaves of the centre span being filled in with thick glass louvres, as are also the fanlights over the large front sliding doors.

"The stalls, boxes, and yard are well supplied with water from a cistern in the mixing-floor, which is fed by gravitation from a spring on higher ground. The walls are built of stone lined with brick, and the build-

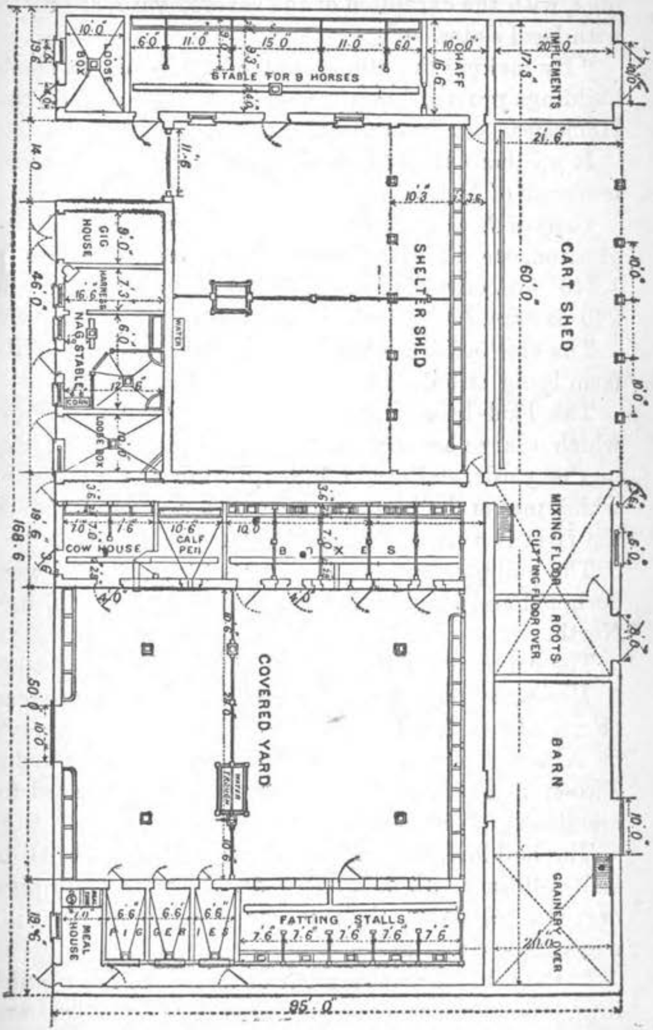

STABLE FOR 9 HORSES
LOOSE BOX
CHAFF
IMPLEMENTS
CART SHED
SHELTER SHED
GIG HOUSE
HARNESS
NAG STABLE
CORN
LOOSE BOX
WATER
COW HOUSE
CALF PEN
BOXES
MIXING FLOOR
CUTTING FLOOR OVER
ROOTS
COVERED YARD
WATER TROUGH
BARN
GRAINERY OVER
MEAL HOUSE
PIGGERIES
FATTING STALLS
168. 6
95. 0

Fig. 19.

ings, with the exception of the covered yard, are roofed with local slates.

"By making the utmost use of materials from old buildings previously on the same spot, the cost of this Homestead barely exceeded £2,000."

It was built from the designs and under the superintendence of Messrs. Baily Denton, Son, and North.

Covered Homestead.—Fig. 20 shows the ground plan of a homestead built in 1881, near Metford, on a farm of 1,240 acs., of which about 1,000 acs. are arable, and 240 pasture.

The new buildings were erected for a portion of the farm lying at a distance from the main homestead.

The land being light is well adapted for sheep, of which a large breeding flock is kept. Beasts are fatted in the yards, stalls, and boxes during the winter, by which means the large quantity of straw produced on the farm is converted into manure.

The buildings are of brick with tile roofs, and were designed and built by Messrs. Baily Denton, Son, and North.

The contract amount was £1,720.

Homestead for a Farm of 400 *acres.*—This homestead (Figs. 21 and 22), is built of iron, by Mr. Humphreys, of Albert Gate Works; the design by Mr. Clarke. Two-storied buildings, which are not so well suited for erections of iron, have been avoided.

The buildings will accommodate 100 cattle (44 in stalls, 40 in yards, 4 in boxes, and 12 calves); 30 pigs, or extra cattle in their place; 9 working horses; 2 nag horses, &c.

In the general arrangement of this set of farm buildings, compactness of design has been studied and adopted for economising material, as well as for facili-

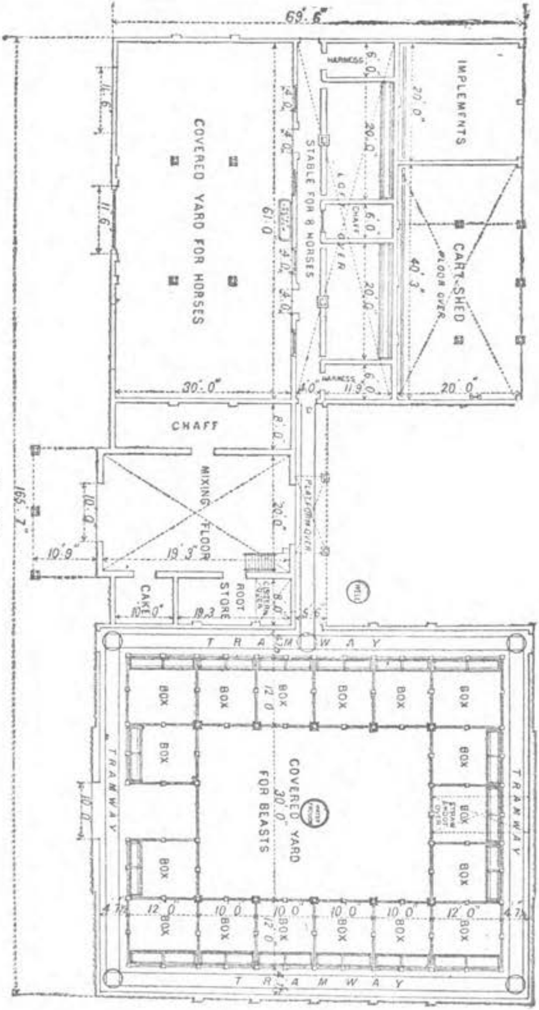
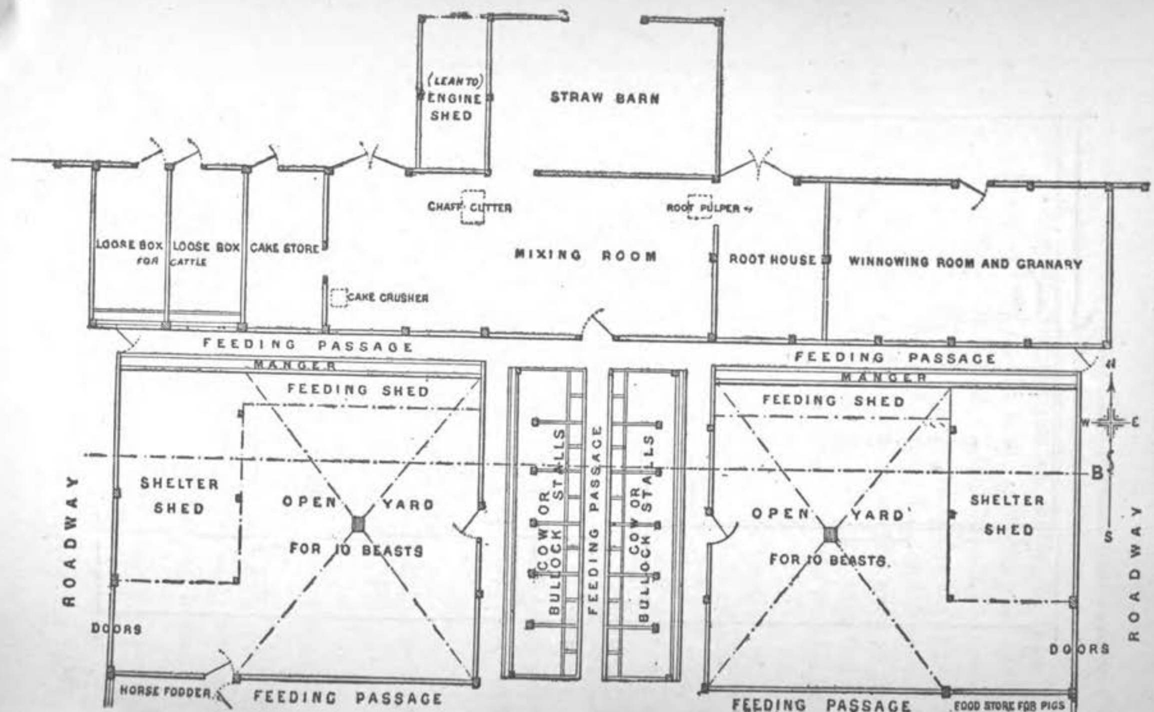
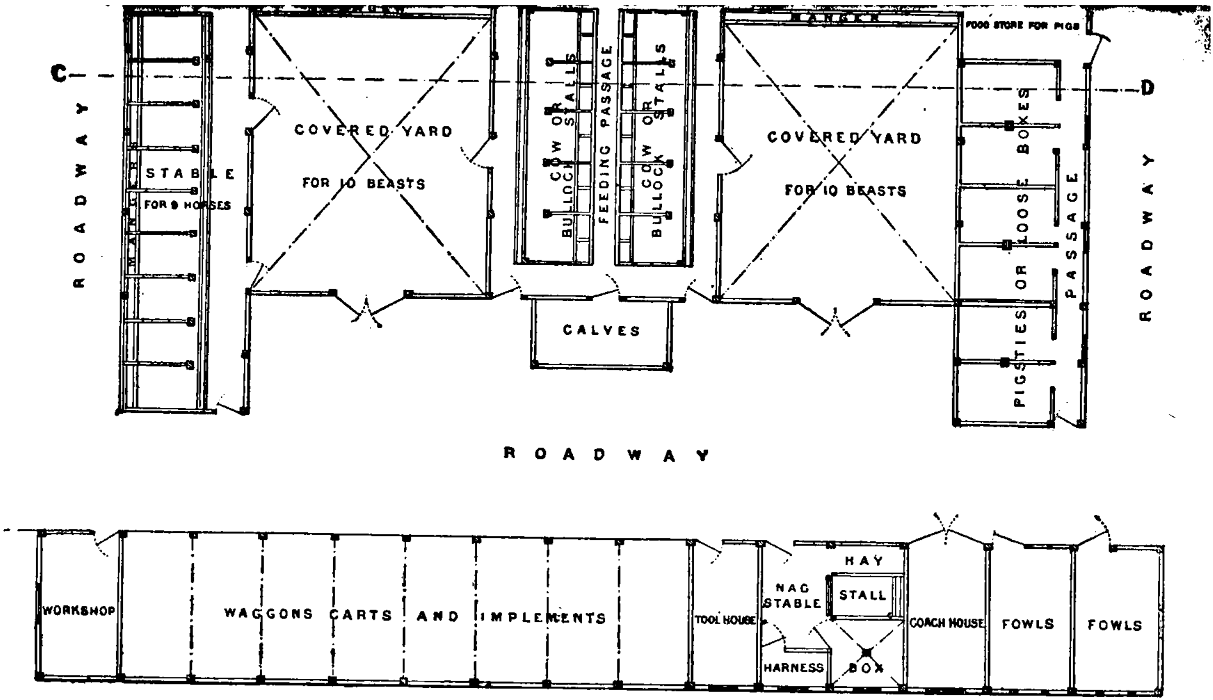

69' 6"
165' 7"
COVERED YARD FOR HORSES
STABLE FOR 8 HORSES
IMPLEMENTS
CART-SHED
FLOOR OVER
HARNESS
CHAFF
MIXING FLOOR
CAKE
ROOT STORE
PLATFORM OVER
WELL
TRAMWAY
BOX
COVERED YARD FOR BEASTS
30' 0"
61' 0"
30' 0"
20' 0"
40' 3"
19' 3"
10' 9"
10' 0"

Fig. 20.

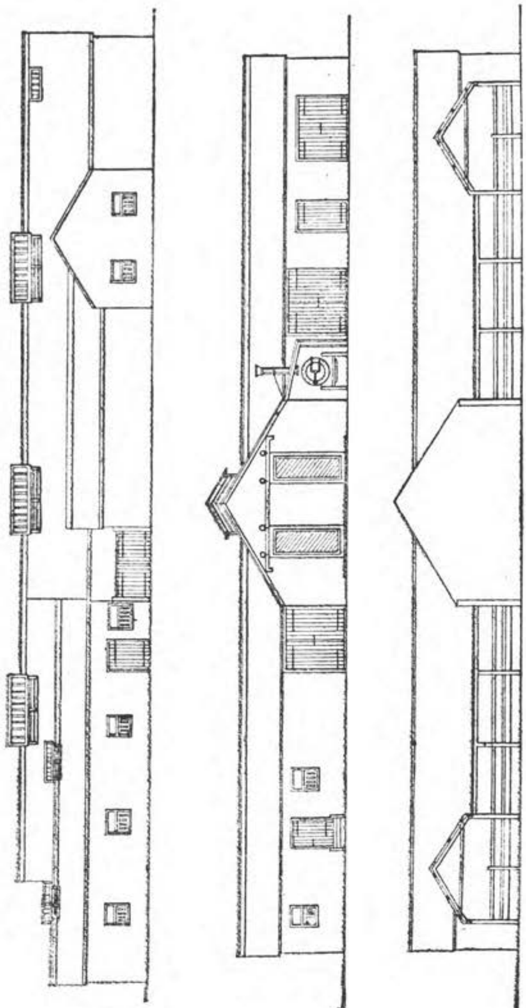


(LEAN TO) ENGINE SHED
STRAW BARN
CHAFF CUTTER
ROOT PULPER
LOOSE BOX FOR CATTLE
LOOSE BOX
CAKE STORE
MIXING ROOM
ROOT HOUSE
WINNOWING ROOM AND GRANARY
CAKE CRUSHER
FEEDING PASSAGE
FEEDING PASSAGE
MANGER
MANGER
FEEDING SHED
FEEDING SHED
SHELTER SHED
SHELTER SHED
OPEN YARD FOR 10 BEASTS
OPEN YARD FOR 10 BEASTS
COW OR BULLOCK STALLS
FEEDING PASSAGE
COW OR BULLOCK STALLS
ROADWAY
ROADWAY
DOORS
DOORS
HORSE FODDER
FEEDING PASSAGE
FEEDING PASSAGE
FOOD STORE FOR PIGS
B
N
W
E
S



C
D
ROADWAY
STABLE
FOR 9 HORSES
MANGER
COVERED YARD
FOR 10 BEASTS
COW OR BULLOCK STALLS
FEEDING PASSAGE
COW OR BULLOCK STALLS
COVERED YARD
FOR 10 BEASTS
FOOD STORE FOR PIGS
PIGSTIES OR LOOSE BOXES
PASSAGE
ROADWAY
CALVES
ROADWAY
WORKSHOP
WAGGONS CARTS AND IMPLEMENTS
TOOL HOUSE
NAG STABLE
HARNESS
HAY
STALL
BOX
COACH HOUSE
FOWLS
FOWLS

Fig. 21.



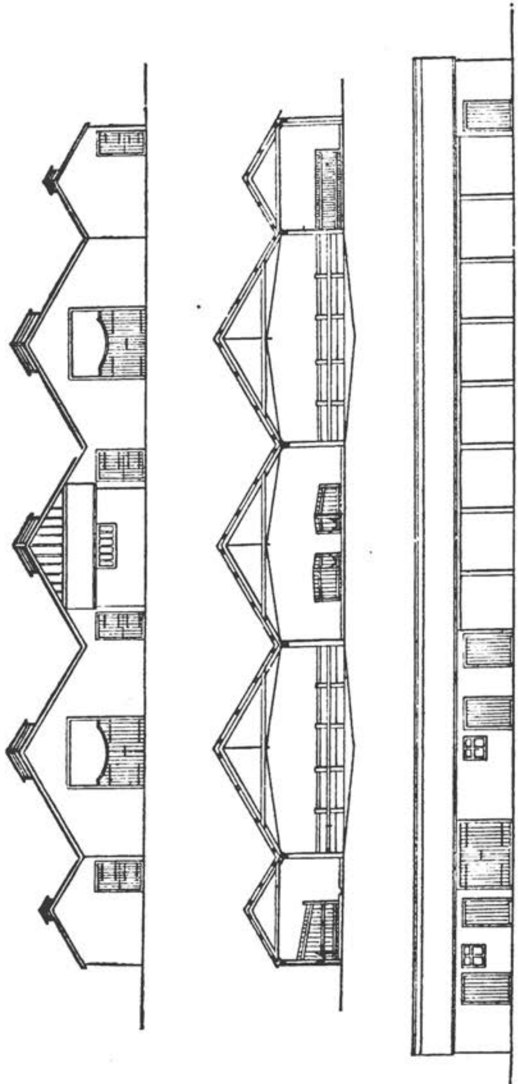


Fig. 22.

tating the every-day work of the Homestead. The various classes of animals are brought as near as possible to their food, and the arrangements for their health and profitable progress will be found all that can be desired.

The range of food stores at the north are complete, and conveniently arranged. The straw, roots, hay, and cake are all closely placed to the mixing-floor, and to the motive power for chaffing, pulping, or grinding. The space for mixing is ample for the purpose, and the food can be placed in the various mangers by means of the feeding passages with the least possible trouble, and without the workmen leaving the covered spaces, there being no intervening roadways to be crossed.

The winnowing-room and granary adjoin the stack-yard, which is a convenient situation, and it is provided with a wooden floor, which is the most suitable for improving or maintaining the condition of grain.

There is access to the cattle-stalls without entering the yards to disturb other cattle; and the manure made can be cast with little trouble into the yards adjoining. The lower portion would be most suitable for dairy cows, as the calf-house adjoins at the south end.

Two of the cattle-yards are open yards with ample shelter and feeding-sheds, and two are wholly covered; but all of them could be covered in without interfering with the surrounding buildings, as plenty of light and ventilation is arranged for in the various roofs, as well as in the gable ends. The yards are constructed to hold ten full-sized beasts in each, but they will of course hold larger numbers of young cattle.

The arrangement of the piggeries will be found very convenient. The 6 pens are 13 ft. × 8 ft. each, large enough for 5 pigs; and are arranged in one house, and approached from the food store at the end by a feeding passage. These are merely divided by a fence 4½ ft. high from the covered yard adjoining, which saves building material and gives a free circulation of air. There are also light and ventilation given in the roof and outer walls. A portable iron furnace could be placed in the food store for cooking the pigs' food. At the same time, the pig pens are so constructed as to be equally serviceable for cattle of any age, if required.

The stable has direct communication with the straw barn and chaff-house by means of feeding passages; and dunging out can be quickly effected into the covered yards adjoining. Light is admitted by sky-lights in the roof, which is the most effective method, and good ventilation is also given there.

The cart and implement-sheds are placed as near to the stables as possible, including a tool-house, to save time in getting men away to their work. These departments have a close working affinity, and much valuable time is saved by having them in close connection with each other. A workshop is also placed at one end of the range.

Dairy Homestead.—This Homestead (Fig. 23) is built with concrete and iron, by Messrs. Hill and Smith. It provides accommodation for 48 cows, with all the appurtenant offices for a dairy farm of that extent.

The out-offices are so arranged that they can be extended at any time without interfering to any extent with the main building.

A concrete box course, 2 ft. high, runs round the byre to protect the galvanized sheets from damage. The framework of the building is of iron covered with galvanized sheets; light and thorough ventilation are admitted at the roof. Fig. 24 shows the ground plan.

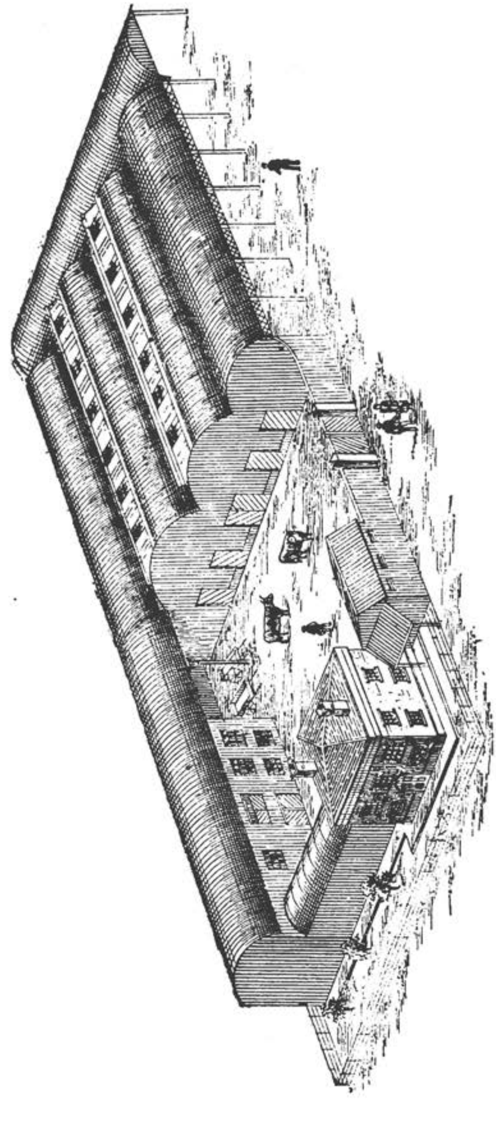


Fig. 23.

The cattle stall head to head, and are thus fed with greater ease and in less time than from behind. The hay and root sheds are arranged conveniently alongside the byre.

The dairy is shut off, and stands separate from the dwelling-house, and is entered by a door under the verandah. The roofing sheets are lined with wood, so as to maintain a uniform temperature inside. Ventila-

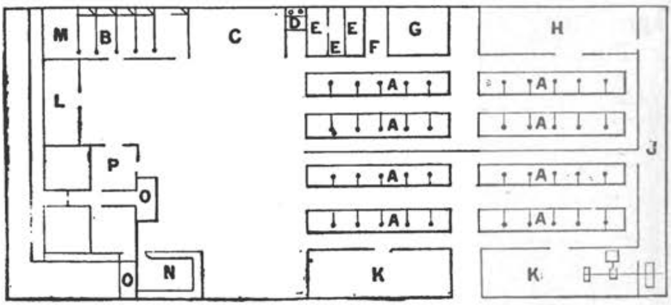


Fig. 24.

A Byres for 48 cows.
B Stables and loft
C Cart shed.
D W. C.
E Pigs.
F Passage.
G Calves.
H Young stock loose.
J Hay and grain shed.
K Roots and feeding stuffs.
L Cattle shed with granary over.
M Tool-house.
N Dairy.
O Verandah.
P Dwelling-house

tion is provided for at sides and ends, and light is admitted by windows facing the yard.

American Barns or Homesteads.—The arrangement most generally adopted by transatlantic farmers is to place the barns, food-store, and buildings for stock, &c., all under the same roof, but on different floors. This plan affords great convenience and economy of labour in feeding stock, and in cleaning out stalls and other daily operations of the farm-yard; and there is no reason why the sanitary arrangements and the lighting and ventilation of the building should not be as perfect as under our English system. The *American Agriculturist* has recently done good service to the farmers of that country by publishing a series of excellent plans of farm buildings of various kinds, for which it had awarded prizes. We reproduce two of these premium designs, which may be usefully studied, perhaps, by agriculturists in this country.

Figs. 25, 26, and 27 show an American farm barn,

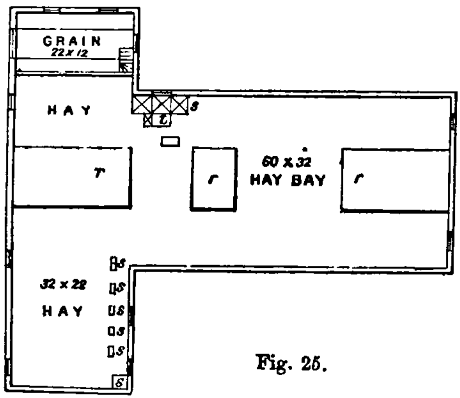


Fig. 25.

by A. A. Wood, Wash. Co. The main floor is seen in Fig. 25, in which there is a grain-bin, with shutes to the floor below; *t*, opening for filling steam chest; *s*, hay-shutes; *r*, *r*, *r*, opening in floor for handling the hay. The granary has shutes to feed the mill below. The ensilage cutter is on this floor, and is run by shafting from the engine-room. Fig. 26 shows the feeding-floor. The steam chest is at *a*; *b*, small boiler; *c*, carpenter's bench; *e*, elevator from root-cellar; *m m*, mixing-troughs; *i*, stairs to granary; *f*, to cellar; *w t*, water-trough; *l b*, loose boxes; *s*, hay-shute to cellar; *t*, trap-door; *r*, trap to root-cellar; *h*, harness closet; *y*, water-tank for cattle; *x x x*, manure-traps. The engine-room contains a portable feed-mill and a forge. The tool-room is large enough to contain all the farm machinery when stored at the close of the season. The floor of this room and all the space over the unexcavated portions are in concrete. The silo is filled from the floor above, or the feeding-floor, as desired. Each floor is 9 ft. in clear, with front and rear doors 12 ft. wide. The cellar is shown in Fig. 27. All partitions are movable, for access of carts tc any part for removing manure.

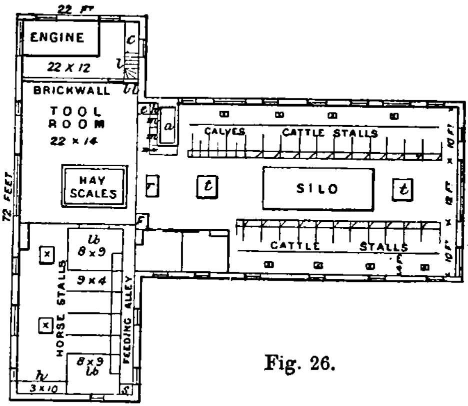


Fig. 26.

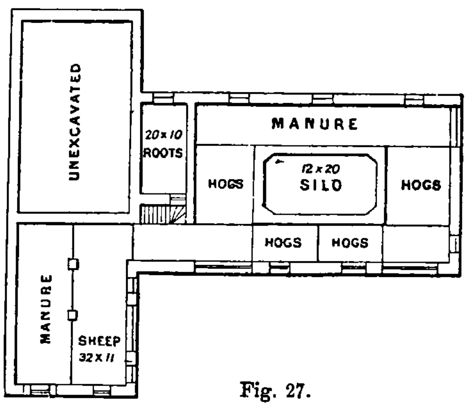


Fig. 27.

The following are the estimates for material and labour in building this barn.

ESTIMATE.

2,600 ft. 4 by 6 in. Posts, Spruce, 18 ft.	
2,000 ft. 4 by 6 in. Sills, Spruce.	
1,200 ft. 3 by 6 in. Plates, Spruce.	
2,600 ft. 2 by 6 in. Floor Joist, Spruce, 12 by 16 ft.	
1,328 ft. 2 by 6 in. Rafters, Spruce, 24 ft.	
864 ft. 2 by 6 in. Rafters, Spruce, 18 ft.	
1,000 ft. 2 by 6 in. Stall Posts, etc., Spruce.	
4,000 ft. 3 by 4 in. Braces, Girts, etc.	
Total, 15,600 ft. at 16 dols.	dols. 249.60
4,500 ft. 6 by 6 in. Sills, chestnut	112.50
60,000 Shingles at 3 dols.	180.00
6,000 ft. Hemlock roof at 14 c.	84.00
9,000 ft. Matched pine at 25 c.	225.00
4,000 ft. Matched spruce at 22 c.	88.00
4,000 ft. 2-in. Matched spruce at 16 c.	64.00
100 yds. Concrete at 50 c.	50.00
1,500 Brick at 10 dols.	150.00
36 Windows at 2 dols.	72.00
11 Windows at 1 dol.	11.00
2 Double Slide-doors	25.00
16 pairs Hinges at 1 dol. 25 c.	20.00
1 Ventilator	20.00
200 lbs. White lead at 7½ c.	15.00
8 galls. Oil at 62 c.	4.96
400 ft. Mouldings at 2½ c.	10.00
Carpenter's work	350.00
140 cds. Stone-work	140.00
Brick-work	105.00
Painting, one coat	30.00
Nails, etc., etc.	35.00
Gutters, etc.	15.00
Total	dols. 2,056.06 = £428 6 11

The Engine, Feed Mill, &c., are not fixtures. A watering arrangement would cost about 1 dol. (4s. 2d.) per stall.

In Fig. 28 we have the design of an American Cattle Barn, by Alfred H. Glover, Saginow, Co. Mich. The main barn is 26 ft. by 42 ft., framed of timber the usual way, with four bents, one at each end, and two centre ones 10 ft. apart. The sheds are 12 ft. by 26 ft., framed of 2 and 4 scantling, the whole double-boarded with inch boards, and tarred paper felt between the boards, with the cracks on the outside battened with 3 in. stuff, and shingled with No. 1, 18 in. shingles, laid 6 ins. to weather. The excavation is 2 ft. below the surface of the ground. The stone foundation, 18 ins. thick, is 4½ ft. above ground; height of cellars, 6½ ft.; height of stables, 7 ft.; height of main barn from stone foundation to top of plate, 13 ft.; from top of plate to top of ridge, 7½ ft.; height of sheds from stone foundation to top of plate, 7 ft. The roof

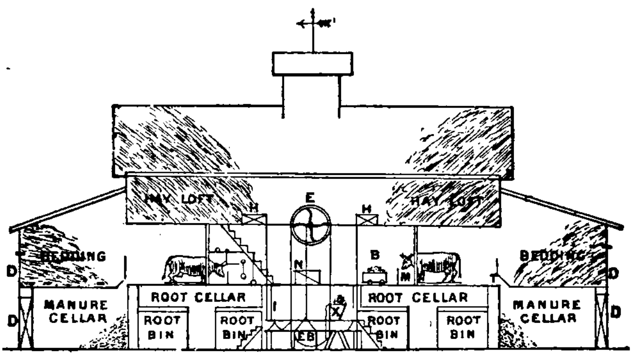


Fig. 28.

is third pitch. The rafters are 2 ft. apart, made of 2 by 4 material. The joists under the stable floor are 2 by 8, 18 ins. apart, joined into the sills, and run across the barn joists. Size of manure-cellar, Fig. 29, with foundations, is 12 ft. by 26 ft.; root-cellar, with foundations, 26 ft. by 42 ft.; P, P, P, P, four stone piers for holding up centre sill; E B, elevator bucket; X, root-cellar; C S, cellar stairs. The stable floor, Fig. 30, is reached by an inclined floor 10 ft. wide, commencing at the front of the barn, 1 ft. above the ground, and rising until it reaches the level of the stable floor, 6 ft. from the rear of the barn. An alley, 6 ft. wide, runs the whole length of the main barn, and four alleys,

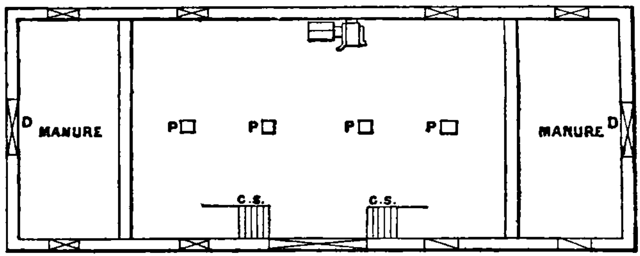


Fig. 29.

4 ft. wide, are at right angles. The cattle stalls are ten in number, 4 ft. by 5 ft. outside of stanchions, with

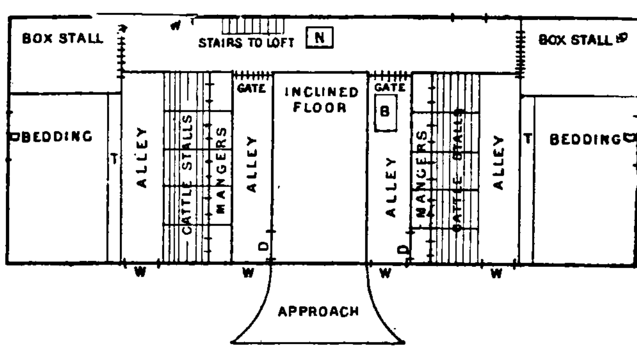


Fig. 30.

partitions 3 ft. high between each stall. The mangers are 2½ ft. wide by 2 ft. deep. The floor in rear of stalls is wall battened, and stands to the rear. The floor inside of stalls is made of strips 2 in. by 4 ins., 4 ft. long, laid in stringers 2 ins. thick and 6 ins. wide. In the rear of the stalls and alley is a trap T, for throwing manure into the cellar. A trap, N, is curbed up, for elevating roots from cellar; B, is a box on trucks, for carrying roots to cows; D, D, slat door to box-stalls. The box-stalls are 8 ft. by 12 ft. The bedding rooms are 12 ft. by 18 ft., and are open to stables from 3 ft. above manure trap. The alleys in front of stalls are closed by a gate. In Fig. 31, H is a curbed trap for throwing

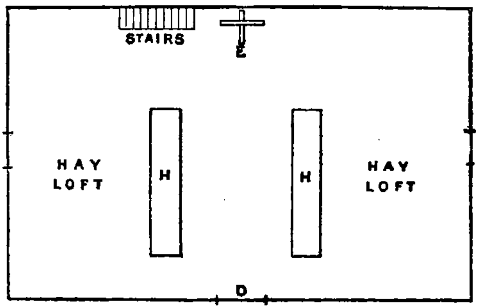


Fig. 31.

down hay; E, elevator. The stairs leading to the loft are 2 ft. wide. There is a shelf under the stairs for holding brushes, &c., and hooks for hanging shovels, brooms, and other tools. There are sixteen 4-lighted windows, glass 16 ins. square. Cellar windows are double glazed. All windows are hung with butts at side. The barn is well lighted and ventilated, and so constructed every way as to secure comfort and cleanliness for the animals, and economy in feeding, storage, and care of food, and in making and saving of manure.

Estimate for Cattle Barn.

Excavation, 127 yds. at 20 c. per yard .	dols. 25.40
2,395 cubic feet of stone at 6 c. per foot .	143.70

Sills, 8 by 12, 278 ft. long.	8 posts, 6 by 6, 10 ft. long.
58 joists, 2 by 8, 14 ft. long.	Purlines, 6 by 6, 84 ft. long.
28 joists, 2 by 8, 12 ft. long.	Braces, 4 by 4, 700 ft.
8 posts, 10 by 10, 13 ft. long.	44 rafters, 2 by 4, 18 ft. long.
4 posts, 8 by 8, 7 ft. long.	28 rafters, 2 by 4, 14 ft. long.
4 girts, 6 by 6, 16 ft. long.	500 ft. joists, 2 by 4, for stalls and other work.
2 girts, 6 by 6, 10 ft. long.	28 joists, 2 by 6, 16 ft.
4 beams, 10 by 10, 26 ft. long.	14 joists, 2 by 6, 10 ft. long.
8 beams, 6 by 6, 13 ft. long.	4 girts, 4 by 6, 26 feet long.
Plates, 8 by 8, 84 ft. long.	

Timber, at 14 dols. per M.	dols. 357.00
2,000 ft. of 6-in. plank for floors at 14 dols. per M.	28.00
11,000 ft. 1-in. boards, at 12 dols. per M. .	132.00
600 ft. battens at 8 dols. per M.	4.80
300 lbs. tarred paper felt at 4 c.	12.00
15,500 shingles at 3 dols. 50 c. per M. . .	54.25
Nails, hinges, &c., 35 dols.; carpenter's labour, 200 dols.	235.00
16 windows at 2 dols. each	32.00
Total	dols. 1024.15 = £213 7 3

CHAPTER IV.

BARNS AND GRANARIES.

The old English barn, with its central threshing-floor and waggon-way, and bays on either side for unthreshed corn, was constructed to accommodate the whole of the grain crop on the farm. The size of these barns, and consequently the great expense of them, greatly exceeded what is now considered necessary for such buildings. They were well adapted for threshing by flail, and the contents can be easily threshed out by a portable steam thresher; but the introduction of modern barn machinery, and the consequent re-arrangement of the homestead, has rendered large barns of the kind a useless appendage to most farms.

Threshing and Dressing Barn.—The modern threshing barn consists of two apartments, an upper and a lower; the former to contain the unthreshed grain and the threshing-machine, the latter the winnowing and dressing machines and the threshed corn.

The threshing barn should adjoin the rick-yard, so that it can be readily filled from the rick-yard waggon or cart through a pitch door in the back or end wall of the upper compartment. This will generally be on the north side of the farmery. The upper barn should be large enough to contain an ordinary stack or corn rick.

The first requisite of a well-arranged threshing barn should be, that the unthreshed grain be easily conveyed direct to the head of the threshing-machine, and that facilities be afforded for housing or removing the straw after it has passed through the machine. In many homesteads the error has been committed of not placing the threshing-machine in such a situation that the straw may be easily and conveniently stowed away after it has been threshed. It is of great importance that facility be given for supplying all the stock buildings with the straw necessary for fodder and litter, whether the straw is first passed through the cutter or not.

Straw Barn.—The best position for this barn is at the end of the threshing barn, so that it receives the straw direct from the machine. Straw for litter will be distributed from this barn, but where there are lofts over the cattle a straw-elevator is attached to the threshing-machine, and the straw for litter is passed on direct to the lofts. Where the chaff-cutter is on an upper floor, it most conveniently occupies the loft between the elevator and the cattle-lofts. The straw barn should be large enough to contain at least a stack of threshed straw.

Granaries.—To fulfil its purpose, a granary must be conveniently situated, dry, well aired, and free from vermin.

The most convenient situation for a granary is either over the threshing-floor or adjoining it. In many cases the granary is placed over the implement and cart sheds, a position which has many conveniences if these sheds adjoin the threshing barn, which, however, they seldom do in very modern-built homesteads. When the granaries are above the threshing-floor, or on a floor which immediately adjoins it, the corn is at once raised from the winnowing-floor, either by elevators or by a windlass working through a hatchway, and deposited in the granary with the greatest expedition and the least labour.

The size of the granary will be determined by the extent of corn land, but the accommodation should be ample. The interior of it should be subdivided into compartments or bins for all the different kinds of grain grown, and for farm seeds, &c. The divisions can be varied in number as well as size to suit the wants of any particular farm.

The floor of the granary should be laid with asphalte or cement, and the divisions made of oak and cement. If the floor has been boarded, all the joints between the boards and between the floor and wall skirting should be cemented, otherwise it will be impossible after a time to keep out vermin.

The bin divisions are most convenient when made 3 ft. high. Some farmers graduate the bins so that the number of bushels in each can be seen at a glance. The graduation is simply performed by drawing a distinct horizontal line of paint on one side of the interior of the bin for every 5 bushels it will contain, and marking distinctly every bushel between the lines. All that is then necessary is to level the surface of the grain, and observe what figure it reaches.

To calculate the contents of a bin, multiply the length, breadth, and depth in feet, and that product by 0·8. Suppose a bin is 10 ft. long, 5 ft. wide, and filled 2 ft. deep with corn, this will give, when multiplied as above, 80 bushels in answer. It takes 2,150 cubic ins. to fill a bushel, and a cubic foot contains 1,728 cubic ins., hence the bushel is to the foot as 2,150 is to 1,728, or about as 5 is to 4, which is the explanation of the use of the fraction 0·8.

CHAPTER V.

FOOD-PREPARING AND MIXING ROOMS.

In a modern farm homestead one of the most essential parts is the accommodation necessary for the preparation and mixing of food. These apartments consist of chaff-cutting room, pulping-room, mill-room, and mixing-floor, and they should be centrally situated in order to insure economy of labour. Not unfrequently they form one large compartment.

On many farms arrangements are made for the preparation of food by an upper floor at the end of the barn being partitioned off to accommodate the chaff-cutter and corn and cake crushers, while beneath is the mixing-floor where the roots are pulped or sliced, and mixed with the chaff supplied from above. In some cases, however, the whole of these compartments are on the ground floor, as is the case of our example homestead for a farm of 400 acres. Under the best arrangements the hay is passed direct from the rick-yard or the hay-shed to the cutting-floor, through a pitch hole arranged for the purpose, and no hay is fed uncut.

Chaff-room.—The chaff-cutting room should be so placed that the greatest facility be given for supplying the machine with the hay, straw, &c., to be cut, and should therefore be in such a position as to open direct into the straw and hay barns. When there is no hay-house, one side of the chaff-cutter room should adjoin the hay-sheds or the rick-yard. It is also necessary that the chaff-room be so placed that equal facilities be given for the supply of the chaff to all the animals on the farm consuming it. It must likewise open into the mixing-floor.

Pulping-room.—This compartment must needs be on the ground floor. In it are placed the root-pulpers and root-slicers. It is best placed so as to communicate with the root-store on one side and with the mixing-floor on the other side.

Mill-room.—The corn-bruisers, cake-breakers, and such like machines find a place in this compartment. The corn-bruiser is usually supplied by a hopper leading from the granary above; and the mill-room affords storage for cake and meal, &c., as well as room for working the various machinery. It should open direct into the mixing-floor.

Boiling-house and Steamers.—Sometimes a separate compartment is devoted to the apparatus for boiling and steaming food, but more generally it occupies a corner in the root-house or in the pulping-room. In the former case it should be contrived, if possible, to connect it with the mixing-floor.

Mixing-floor.—This is best placed when it opens on one side into the pulping and mill rooms, and on another side into the straw and chaff rooms. On the third side it should have convenient access to silos, hay-sheds, and rick-yard. On the fourth side it should communicate in the most direct manner possible with the cow-houses, feeding-stalls, covered or open yards, piggeries, and stables.

CHAPTER VI.

HAY OR GRAIN SHEDS.

SHEDS for storing hay and grain are now indispensable. The great advantage of them in this fickle climate is that the hay or grain is safe immediately it is under the shed, without the delay of thatching. They also admit of hay or grain being sooner carried than when it has to be stacked; besides which the straw for thatching is not always conveniently available, and even when it is available many farmers think it can be better used. For all these reasons, open-sided sheds or Dutch barns for storing hay and grain have of late years been much in demand. And if a silo can be combined with one of these sheds, it is not unlikely that the entire forage crops of the farm will soon be stored under cover.

The quantity of hay that can be stored in a shed is easily calculated. The weight of a haystack varies according to the density, but it seldom exceeds 1 cwt. per cubic yard. A rick of moderate size, when newly built, may, in ordinary cases, weigh about 75 lbs. per cubic yard. A large rick may weigh 100 lbs., and when the hay is old, about 125 lbs., per cubic yard.

Hay and grain sheds are now generally covered with self-supporting corrugated iron roofs. The framework and pillars may be either wood or iron.

Dutch Barns.—An excellent shed of this kind is illustrated in Fig. 1. It is an iron roof on wood posts or iron pillars, and can be constructed in one, two, or three spans, as desired. Ventilation is given at the roof and at the gables. If required it can be fitted with vermin-proof rick-stands.

Derbyshire Hay Barns.—These barns have of late been attracting much attention, as they are constructed with rising and falling roofs, and so can be made use of for a great variety of purposes, while they cost but little more than the Dutch barns. When the barn is filled with hay, the roof can be let down close to it, which prevents the top hay becoming dusty. Again, when emptied of hay the Derbyshire barn roof can be lowered to within 6 or 8 ft. of ground, when it makes a capital shelter shed for cattle; or it may be used as a lambing shed when wanted.

The general construction of the Derbyshire Barn will

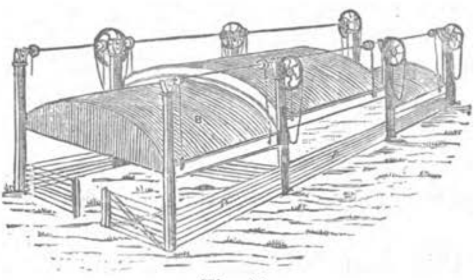


Fig. 32.

be understood from Fig. 32, which represents one of Henson & Co.'s erections with wood posts, wood frame, and iron top. The roofs rise or fall in 15-ft. sections, and can rise 18 ft. to eaves, and be lowered to within 6 ft. of the ground. The roofs are raised by Henson

& Co.'s patent lift, and will stop at any given point. Each section overlaps the adjoining one, so as to keep out all wet. A shed of the above description, 30 ft. long by 18 ft. wide and 16 ft. high, can be erected at a cost of £34.

Our illustration shows the shed with the roof lowered,

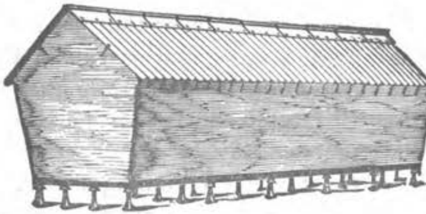


Fig. 33.

and side hurdles fixed so as to form a covered enclosure for sheep and cattle. By using corrugated sheets the sides of the barn can be quite enclosed.

Iron Rick-Covers.—Pearson's * corrugated sheets are now much used for covering ricks. The ridging, as indicated in Figs. 33 and 34, has hook bolts fixed to it every 2 ft. apart, to which the corrugated sheets are attached. To the bottom end of each sheet a chain and iron pin are attached, the latter for inserting into the side of the rick and binding the entire cover tightly down.

With these iron covers the pitch or angle of roof need be much less than in ordinary thatching, as the slightest inclination will carry off rain, snow, or sleet.

These corrugated iron sheets are waterproof and fireproof, and they save the time, straw, &c., necessary for the old system of thatching, a rick 36 × 18 ft.

* Thos. Pearson & Co., Wolverhampton.

being covered in half an hour, or less. They are easily and rapidly fixed by an ordinary labourer and easily removed, and their durability may be reckoned at from

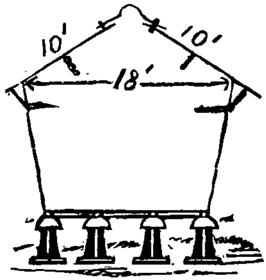


Fig. 34.

twenty to thirty years. The sheets can be used for many purposes besides covering ricks, such as forming a temporary or permanent roof for a shed or pen for cattle or sheep, &c

CHAPTER VII.

SILOS.

"SILO," meaning literally a pit, is the term given to the tank, cellar, or building used for storing or preserving green fodder; and the grass or other green stuff thus treated is called "ensilage."

To M. Goffart is due the honour of applying the ensilage system on a large scale to agriculture, as at present practised. American farmers at once adopted it with success for the treatment of maize or Indian corn; and, during the last year or two, ensilaging crops has been practised in various parts of Britain, and found to answer well for the preservation of fodder crops grown in this country.

Ensilage can be made from clover, meadow-grass, green corn, and in fact all green fodder. The green crop is taken from the field immediately it is cut, without allowing it to wither, and with all the juice or sap in it. The latest experience on the subject shows that young grass can be safely ensilaged; and that is important, for if succulent matter like the "after-math," green clover, vetches, and comfrey can be ensilaged, the dairy-farmer need never be at a loss for green food in winter and early spring. Moreover, the ensilage system gives an easy means of preserving late crops at a time of the year when it is almost impossible to make hay. Brewers, it is said, are now pitting their grains, and those ensilaged come out grain cakes that preserve, as food for milk cows, the valuable properties of the fresh grains. It is even possible that means may yet be found of making ensilage an article for the markets as well as for consumption on the farm.

The green forage can be preserved in the silo for any length of time, and fed out to the cattle as required. And, as M. Goffart and others have shown, the nutritive properties of green ensilage is not only greater than if the grass had been converted into hay, but, of the two, the ensilage is the most palatable and most relished by the stock. Horses and sheep can be fed with as much advantage as cows upon ensilage. For winter feeding it is unsurpassed, as it produces the same effect on cattle as green grass does in the summer months. Milk cows yield more milk on ensilage than on any other kind of food. At a recent conference of farmers in America, it was declared that ensilage, by increasing the yield as well as greatly improving the quality of the milk of cows fed upon it, had effected a complete revolution in the dairy-farming of that country. The conference was also unanimously of opinion that ensilage mixed with albumenoid food, would admit of a given area of land supporting three or four times the stock which could otherwise be maintained on it.

"In short, this system, extensively adopted, may be said, as far as farmers and the feeding of cattle are concerned, to extend summer into winter. Particular attention should also be given to the most important fact that the ensilage of green grasses will entirely dispense with the great expense and risk of haymaking; and in the case of late second-cut lucerne, sainfoin, &c., at a season when there is little or no chance of making hay, the system will be found of great value. With this nutritious food at hand, farmers will grow a less extent of root-crop, and a less sum will need to be expended annually in feeding-cakes and artificial manures."

If, indeed, ensilage has only half the success that has been predicted for it, its adoption will save millions annually to our farmers.

Position of Silo.—In planning a set of new buildings, with reference to feeding ensilage, the silo, like the mixing-floor, should be so placed as to afford easy communication between it and the cow-houses, the fatting-stalls, and cattle-yards. But on farms already provided with buildings, the best position for the silo will be largely determined by the established arrangement. In some cases the silo may be built so that the roof of the barn can be extended to cover it; in other cases it may answer best to build it within an old barn, or under the roof of a grain or hay shed. It should be in a position convenient for filling it, and at the same time affording equal facility for emptying it and distributing its contents amongst the stock to be fed from it.

Construction of Silos.—The silo should be narrow and deep rather than broad and shallow, both to make the forage easily pressed and to economise roofing. An oblong form is therefore best, but the pit may be of almost any dimensions. There may also, if desirable, be two or more silos alongside, separated by partition walls.

Pearson's* system of combined silos and corn or hay

* Thos. Pearson & Co., Wolverhampton.

sheds will at once commend itself to the farmer, as of a most useful character. The same roof is made to cover the silo, and also to form, with the addition of columns, a barn or hay-shed. Permanent sheds or roofs of this class are recommended as the cheapest in the end, and are certainly the best, as such permanent sheds are not to be reckoned as part of the cost of ensilaging fodder, since they soon earn their cost as shelter for corn or hay, saving, as they do, the labour and straw necessary in ordinary thatching; and again, when the shed is filled, the contents serve as additional weight for the silo. Besides, the combined structure economises space where it is of the greatest value, viz., adjoining the cattle-sheds and farm buildings. The silo, when not filled with ensilage, may be used for storing roots, straw, and other produce.

A cross-section of one of Pearson's combined silo and grain-sheds is shown in Fig. 35. The shed, it will be observed, is about 4 ft. larger than the silo all round.

When the pit is dug, the floor, sides, and ends are built with stone, brick, or concrete, as may be cheapest. The thickness of the walls need not be more than 4½ in. of concrete, or half a brick when laid in cement. The lateral pressure when the silo is weighted is really very little, for the shrinkage takes place laterally as well as vertically. Thick walls in excavated silos are, therefore, a useless expense, all that is needed being that the sides and floor of the pit be made watertight. Party walls would require to be 9 inches thick. The walls should be smooth and perfectly upright on inside, so that no resistance is offered to grass settling down when weighted. Concrete is recommended, as, in almost all cases, it will be found the cheapest material, besides enabling the silo to be quickly constructed, and making it thoroughly watertight, which must be secured. The mixture for concrete may consist of 1 barrel of cement, 3 of sand, and 4 of clean gravel or rubble. In some silos a gutter is formed from end to end of floor, which communicates with

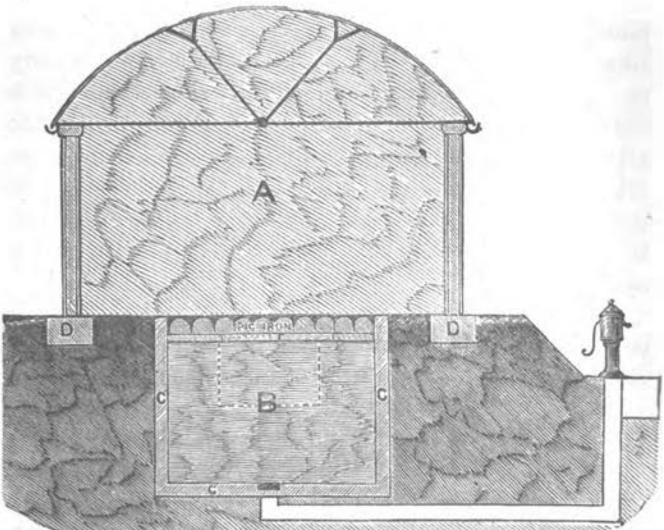


Fig. 35.

A, Produce stacked in shed, and serving as additional weight on ensilage; B, ensilage covered with boards and weights; C C C, concrete walls and floor; D D, concrete blocks or foundations for girder columns.

outside drain, to allow of any water that may gather in the silo being drawn off.

At one end of the silo a slot doorway is made, with an easy slope or gangway outside leading down to it. Grooves should be formed in the walls at each side of the door, and the doorway closed by strong boards,

$1\frac{1}{4}$ in. thick, being slipped into the grooves. This doorway is convenient when ensilage is being removed, in particular if the shed above has not been emptied, or when a horse is employed for trampling the grass. If it is desired to use the ensilage before the shed is emptied, strong planks must be laid across the mouth of the silo after filling it, to form a floor for supporting the produce to be stacked in the shed. The silo can thus be emptied at any time without disturbing the produce in the shed.

Of course there are many other ways of constructing a silo. Sometimes it is formed entirely above ground, with walls of masonry, brickwork, or concrete; but a plank silo preserves the fodder quite as well, and costs but a trifle in comparison. Sometimes the silo is built partly below and partly above ground; and in other cases it is simply what the name implies—a trench in porous soil, and the fodder, weighted with earth, thrown on the top of it. In most cases it must be cheaper to dig out than to build; but the pit system seems to offer most advantage where a hill-side can be turned to account.

Filling the Silo.—The secret in filling the silo is to pack closely, excluding all the air possible. It is merely to make the forage pack closer that corn-stalks, clovers, and grasses are chopped or cut up before being put into the silo; but grass ensilage does not require cutting.

The fodder, when mown, should be got into the silo as quick as possible. It does not keep so well if allowed to lie and wither. Crops for the silo are best cut when young and succulent. The stronger the stems of the plants, the more weight will be required to compress them to exclude the air. Rain need not prevent the storage of crops in the silo. More damage is likely to arise from letting the crops lie long on the ground, than from pitting them in a moist or even wet condition; but, for all that, an excessive quantity of water should be avoided. Salt is not required for the purpose of preserving the fodder, but a moderate quantity may be useful to the stock; from 3 to 4 lbs. per ton, scattered evenly throughout the mass. The fodder when put into the silo should be spread evenly to prevent lumping, and trodden well down alongside

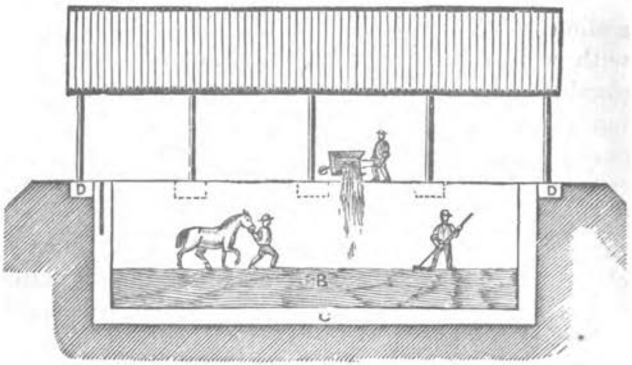


Fig. 36.

walls. A horse may be taken into the silo and used for treading (Fig. 36*); but the men can first tread round the edges with their heels. When the silo is filled with grass, a layer of dry straw that will not mat together, but will allow the air to escape freely as the mass becomes more and more compressed, should be laid upon the contents. When there are several silos, it is best to introduce only a foot or two of fresh fodder into each of them daily. By this means the fodder

* Thos. Pearson & Co., Wolverhampton.

packs closely; but if this plan is not convenient to follow, the silo may be filled and the weights put on at once. When the mass has settled down, the weights and boards may be taken off and the silo again filled to the brim, the planks and weights being again put on.

Weighting the Silo.—Before putting on the weights, boards 2 ins. thick should be laid upon top of the straw covering the grass. The boards need not be tongued or made to fit with great closeness. A few crevices are useful in permitting the escape of air from below, which must be forced out by the weight above if this is to keep well; and if the mass is well compacted, and the weights are kept on, air is not likely to get in afterwards. With the best formed silos and the smoothest walls, the weights should not be less than 1 cwt. to the square foot of surface; but the weight applied in some cases has been as much as 5 cwt. to every square foot. The weights used are either blocks of iron or concrete, or square wooden boxes filled with stones, bricks, or clay. Loose earth is not recommended for the purpose, as it is apt to get mixed with the fodder. Pig-iron is recommended by Pearson as the most suitable for the heaviest kind of pressure, and as being easiest handled; besides which it is always saleable, and loses nothing in use. Stones, or boxes filled with clay, will, however, be a cheaper weighting material. The present plans of weighting are, however, all so expensive and clumsy that we may reasonably expect before long to see some improved method of compression introduced. The want of this seems to be the only drawback to the general adoption of the ensilage system.

Opening the Silo.—When the ensilage ceases to settle, it is considered ready to feed. Six or eight weeks will probably elapse before it is compact enough to resist further pressure. The opening should be made by removing one or two of the planks closing the doorway. The boards and weights should be removed from only a small portion of the surface, and a vertical section made so as to cut out a slice of sufficient thickness for the day's consumption. The ensilage is then cut out with a knife, the same as if it were an ordinary hayrick. The continuance of the pressure during the period of cutting out for consumption is most important. If the weights be taken off in advance, mischievous results may ensue. The more perfect the ensilage has been kept, the less fermentation will have taken place in the silo. Exposure to the air, under such circumstances, is desirable for a few hours, in order to set up alcoholic fermentation before giving the food to the animals. From 40 to 50 lbs. ensilage, mixed with a little crushed oats, is reckoned a day's feed for a cow.

Capacity of Silos.—"One ton of ensilage occupies 50 cub. ft. of space, and as little or no weight is lost in converting grass into ensilage, both may be said to occupy 50 cub. ft. of space per ton. In round numbers it takes 3 tons of grass to make a ton of hay, and allowing 2 tons of hay to the acre, we have thus 6 tons of grass or ensilage per acre. Occasionally, however, with a very good crop, this weight of grass will be doubled. A silo 30 ft. long × 10 ft. wide × 10 ft. deep = 3,000 cub. ft. ÷ 50 cub. ft. per ton = 60 tons of ensilage, or the average produce of 10 acres. For every acre of grass to be made into ensilage, 300 cub. ft. capacity of silo is required."

Cost.—The cost of building a silo, Mr. Baily tells us, should be about 5s. for every ton of capacity; pits or excavations on hill-sides should cost less. It is notorious, however, that many of the silos constructed in this country have cost 30s. and even 40s. per ton of ensilage capacity. These figures are not, perhaps, fairly representative; but the first cost as yet appears to average something like from 12s. to 18s. per ton. Of course the larger the silo, the lower the price per cubic foot of building. And in most cases the first outlay is infinitesimal compared with the advantages; for 5 per cent. on the outlay does not amount to more than 6d. to 9d. per ton of ensilage annually. The cost of making ensilage is at the same time very much less than would be incurred in making the same amount of grass into hay. The former will cost on the average about 7s. 6d. per acre, while haymaking costs from 15s. to 25s. per acre, and the hay often ill-made at any price.

The Merton Silos.—On the Home Farm of Lord Walsingham, three very excellent silos were made in the bay of a barn by the bay front (facing the cart-way of the barn) being bricked up with a 14-in. wall to within 3 ft. 10 ins. of the tie-beam, and by building two division walls of the same description. Each of the silos thus formed was 14 ft. 4 ins. in length, 6 ft. 3 ins. in width, and 9 ft. 3 ins. in depth, and capable of containing about 16 tons of grass or ensilage. The barn floor was laid with asphalte, and the walls covered with a ½-in. coating of cement, which was found to answer well. The total cost of the three silos did not exceed £30. The cost of making the ensilage was about 12s. 9d. per ac., as against the 25s. or 26s. per ac. usually expended on the same farm in making hay. The effect of the ensilage on the horses to which it was given was very remarkable; and in the course of a month's trial, feeding it to five short-horn cows, there was an increase in the daily milk return of fourteen quarts, while the proportion of cream registered by the lactometer gave the astonishing increase of from 12 to 16 degrees. Its effect in increasing the milk of lambing ewes was also very decided.

The Peckforton Silos.—At Peckforton, Lord Tollemache has converted an old Dutch barn into four silos, with the express object of testing a cheap method of ensilaging crops for the benefit of his tenantry. We have to thank his lordship for furnishing us with the annexed plans and particulars.

The barn as it stood, was built on ten pillars, with the back and two sides bricked and the front open. The front was bricked up to a height of 18 ft., while the division of the silos was made by a double half-brick wall running from each of the three pillars in the centre of the barn to the back. This is shown in

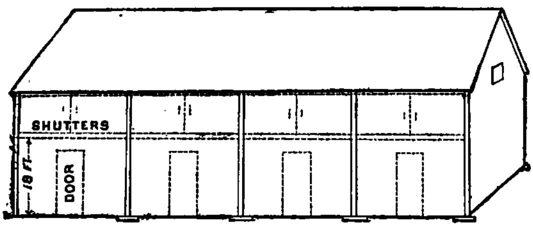


Fig. 37.

Figs. 37 and 38. Each of the silos is 15 ft. long by 12 ft. wide. The first three are 18 ft. deep; but, in order to test the effect on the ensilage of its being kept underground, No. 4 silo has been dug out to a further depth of 3 ft., thus making it 21 ft. deep.

The brick walls were coated with cement, and the floors were laid with concrete. There is a door in the front of each silo, and above the doors and below the roof there are movable shutters for convenience in filling the silos. The capacity of each of the three first silos is 1,402 cub. ft., while that of the fourth is 2,091

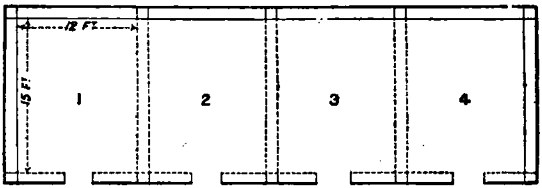


Fig. 38.

cub. ft. This gives a capacity for all the silos of 6,297 cub. ft. At 42 lbs. of ensilage to the cub. ft., the silos should, therefore, be capable of holding 118 tons.

The Peckforton silos, after being filled with meadow-grass, in July last, were weighted with boxes of gravel 42 to each silo. The boxes weigh 1½ cwt. each. On opening the silos in November, the ensilage was found sweet and good, and was eaten with relish by horses and cattle. It is intended to leave a portion of the ensilage until the spring to test its keeping qualities.

Portable Silos.—The portable silos introduced by Mr. Lascelles are deserving of notice. Those sent out by Mr. Lascelles are constructed of concrete slabs bolted in wooden framework; and concrete slabs are used for weighting with. The materials for a silo of this description 12 ft. long, 12 ft. wide, and 10 ft. high, are supplied for £16. As a silo of these dimensions will contain 27 tons of ensilage, the first cost may be put at 11s. per ton. Larger silos, however, are comparatively much cheaper; one of Mr. Lascelles

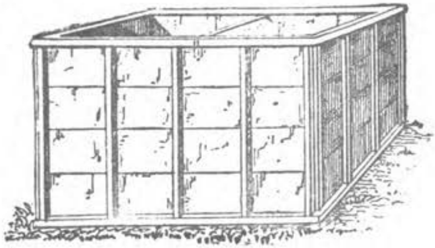


Fig. 39.

estimates showing that it is possible to reduce the first outlay to something like 3s. per ton of capacity.

CHAPTER VIII.

BUILDINGS FOR CATTLE.

THE buildings for cattle include cow-houses, calf-pens, stalls, boxes, covered yards, and sheds with open yards.

The superficial space allowed for full-grown animals in each case varies. In cow-houses and stalls the space allowed each beast is about 72 ft. super.; in boxes, 90 ft.; in covered and open yards, 100 ft. These figures take the space between wall and wall, and include that occupied by the manger and trough. Young stock can be kept in greater numbers, according to age and size; but much also depends upon the breed, the animals of some breeds being so much larger than those of other breeds.

Glazed earthenware troughs are best for cattle, as they are most easy to keep clean. Water-troughs are now fixed in all the cow-houses, boxes, stall, and yards of well-arranged homesteads.

Cow-houses.—Cow-stalls are often placed against the wall, but the best plan is to have a passage in the front, by which the food may be brought and placed in the troughs or racks, and all the dirt is by itself in the passage behind. In large establishments tramways run down these passages for the conveyance of the large quantities of food required. The feeding passage may be paved either with bricks like the other parts of the floor, laid with concrete or asphalte, for here the cattle never come.

The cheapest form of cow-house for a large number of cows is one in which the cows are placed in a double row down the whole length of the building, with a feeding passage between, the animals standing head to head.

The width of a single building should not be less than 19½ ft. from wall to wall, apportioned as follows:

	Feet
Feeding passage in front	5
Manger	2¼
Standing	7
Gutter	1¼
Passage behind cows	4
	19½

In a double cow-house the same 5-ft. feeding passage will still suffice, so that the total width need not be more than 34 ft.

Cows are sometimes tied in pairs, but more frequently there are no stall divisions. The width of stall room allowed to each cow should not be less than 3 ft. 6 in., and need seldom be more.

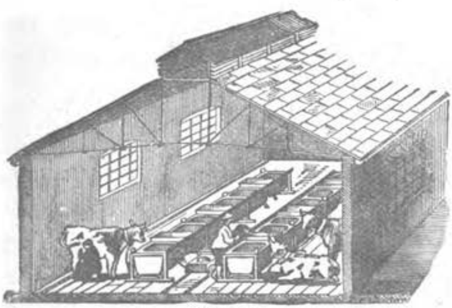


Fig. 40.

The arrangements described above are all fulfilled in the cow-house illustrated in Fig. 40, the animals standing in a double row face to face, with no stall divisions between them. The cow-house is fitted with Cottam's portable united cow fittings.

The best and simplest mode of fastening cows is with a strap round the neck, and a chain halter with a ring sliding on an iron rod, as shown in the above illustration.

In new byres, the old mode of fastening by placing the neck of the cow between stanchions, also the bakie and the cattle seal or binder, should be excluded.

Calf-Pens.—The calf-house should adjoin or be near to the cow-house. A proper calf-pen will be warm and dry, while it is well ventilated and airy; and it should be well lighted from the roof. The best floor is one of asphalte. The drainage must be good, and the pens must be kept sweet and clean and well littered.

The superficial space allotted to each calf is about 16 ft. It matters little whether the calves are tied up separately, or are put into cribs containing one, two, three, or more. They do extremely well when tied by the neck, with a manger in front for containing sliced roots, hay, and oilcake. This plan, and also that of single cribs, has the advantage of preventing the calves sucking one another, from which bad diseases are often engendered. A single-calf crib or pen should not be less than 4 ft. by 4 ft.

Stalls for Cattle.—Stalls for fattening cattle are constructed and arranged very much after the pattern of cow-houses or byres. The cattle are never tied up singly, but in pairs; otherwise there are no divisions between the stalls. The width from wall to wall should not be less than 18 ft., and the width of stall allowed each bullock should be 3½ ft. A plan of feeding stall and fittings as erected by the St. Pancras Ironworks Company is here given (Fig. 41.)

Both in the cow-house and here the cleaning passage

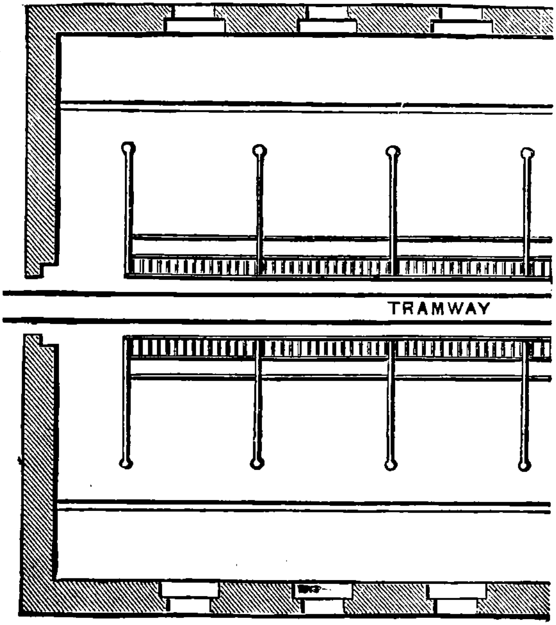


Fig. 41.

behind the animals should open directly into the covered yard.

Boxes for Cattle.—The box differs from the stall in that the animal is not tied up, and that the litter is allowed to accumulate and be trodden into a compact mass. The floors of the boxes should be sunk 2 ft. or more below the door sill, and laid with cement or concrete, so that none of the liquid manure escapes. Litter is added daily in such quantities as is necessary to absorb all the urine and keep the animals dry and comfortable, but not more. The straw for litter should previously be cut into 3 or 4 in. lengths. The mangers should be made to shift higher as the litter accumulates

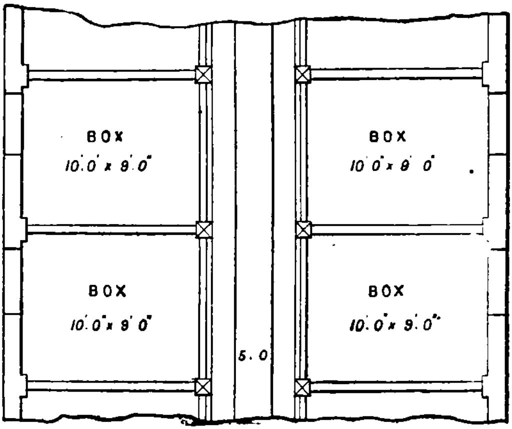


Fig. 42.

in the box. Not less than 90 superficial feet of box room should be allowed to each beast. The boxes may be arranged in a double row with a tramway and feeding passage between, as in Fig. 42, which we transcribe from Mr. Denton's "Farm Homesteads of England."

Separate boxes must be provided for bulls, and these may be constructed in the same manner as for the fattening oxen, except that they should be not less than 12 ft. by 10 ft.

Covered Yards.—The majority of farmers who have had experience with covered yards are now agreed that they are not only better than open yards for all classes of stock, but that they are superior to stalls and boxes for fattening cattle even. At the same time the manure is more cheaply and better made in covered yards than in stalls and boxes.

Small covered yards affording accommodation for 6 to 10 beasts are better than larger ones. The space allowed each beast varies from 100 to 120 ft. superficial. Assuming that the cost of a covered yard is as much as 10s. per square yard, the cost per bullock will then be from £5 10s. to £6 15s. Interest thereon at 5 per cent. will be 5s. 6d. to 6s. 9d. Against this, as compared with open yards, there may fairly be claimed, at the lowest estimate, a saving per head of £2 10s.

	£	s.	d.
Increased value of manure . . .	1	0	0
Saving of straw	0	16	0
Saving of food	0	14	0
	£2	10	0

When the covered yard has a projecting roof at the top, overlapping the lower part of the roof on both sides, and air also coming in all round at the wall-plates, and at the ridge-tiles or ventilators, young and growing cattle even thrive better under those conditions than they do in sheds with open yards.

Open yards are destined soon to be a thing of the past.

CHAPTER IX.

FARM STABLES.

ALTHOUGH there is no necessity for fitting up cart-horse stables in that style of magnificence which is sometimes bestowed on the accommodation for hunters, carriage and racehorses, yet the farmer's horses are nevertheless as much entitled to a comfortable habitation as any of these. Many farmers and landowners seem to think, however, that any sort of a hovel is good enough for a work horse.

Even many recently-built cart-horse stables are notoriously defective in some points of construction, particularly as regards ventilation and drainage.

The old plan of a farm stable with a hay-loft over it, is very convenient for the men, but the arrangement is bad for the horses. The hay-rack, where there is a loft to the stable, is invariably fixed to the wall above

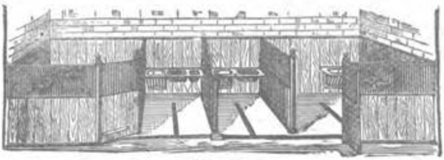


Fig. 43.

the horse's head, so that it can be filled from the floor above; and the manger is considerably under the rack.

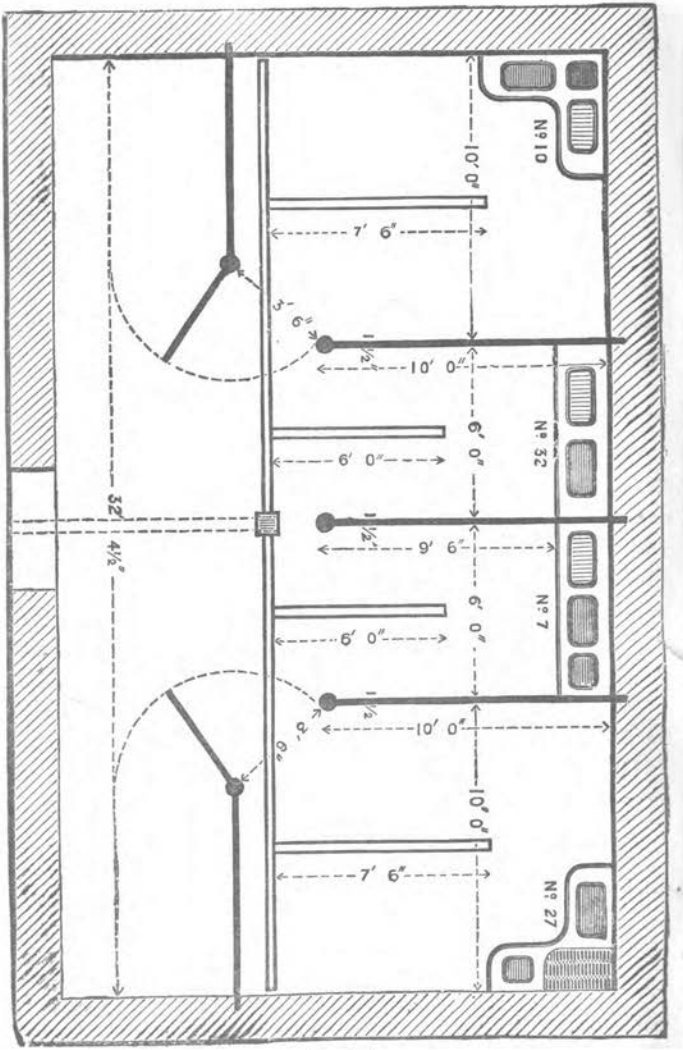


Fig. 44.

What we object to most, however, is that there is absolutely no provision for ventilation and drainage. The stable, moreover, is not well lighted with the loft over it, and the stalls are both too short and too narrow. The consequence is that the hay in the loft is always fusty, and that the horses are seldom in health and condition.

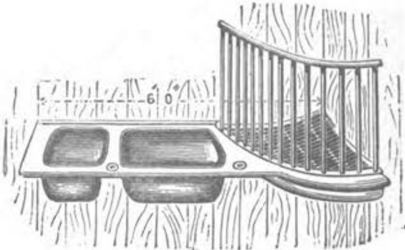


Fig. 45.

Fig. 43 shows a stable fitted by Messrs. Bayliss, Jones, & Bayliss. The arrangement of this stable is for two stalls and two loose boxes. Stall divisions are made $9\frac{1}{2}$ to $10\frac{1}{2}$ ft. long, from wall to heel-post, by $4\frac{1}{2}$ ft. high to rise of ramp; the plain division consisting of heel-posts, sill, and ramp-rail, all of which are fitted to receive boarding $1\frac{1}{2}$ in. thick. The stalls are 6 ft. wide.

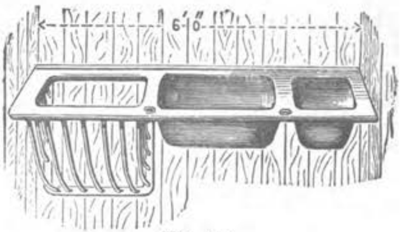


Fig. 46.

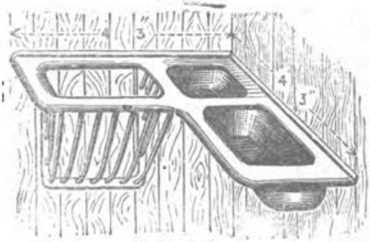


Fig. 47.

Fig. 44 exhibits the ground plan of the same stable. The plans, however, may be varied indefinitely, either stalls alone, or loose boxes alone, or both combined, as here shown.

The manger fittings in these stables are wholly of iron. Some variations of those employed are illustrated on a larger scale in Figs. 45, 46, and 47.

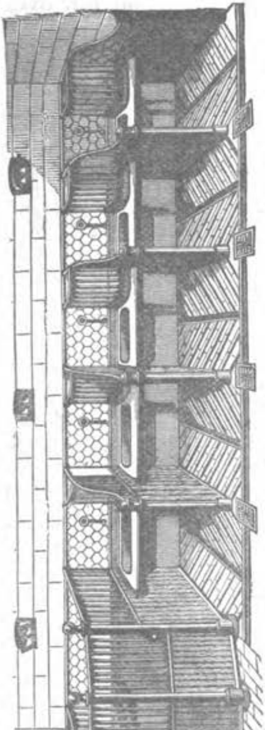


Fig. 48.

Extra large mangers are furnished for stables where chopped food is given; and in such cases the hay-rack is often dispensed with.

A different arrangement as to fittings is adopted in a stable of five stalls and one loose box, recently erected by the St. Pancras Ironworks Company, and illustrated in Fig. 48. Many horse-owners and horse-keepers prefer the hay-rack in the position it occupies in these stalls in preference to having it higher or lower.

Stall Divisions.—The stalls in cart-horse stables ought to be not less than 6 ft. wide, and the divisions must be strong enough to resist the pressure and kicks of the horses. An extra strong iron post, ventilating ramp and sill, is made by Cottam & Co. for cart-horse stables, Fig. 49. It should be fitted with Cottam's patent Dovetail Wedge Sill.

Many horses have a habit of kicking the stall partition until the boards become broken; and no plan has hitherto been discovered of replacing these boards without entirely removing the ramp or railing surmounting them, which is a matter of serious trouble and expense. With the dovetailed wedge sill, however, broken boards in the stall divisions can be removed and re-

Fig. 49.

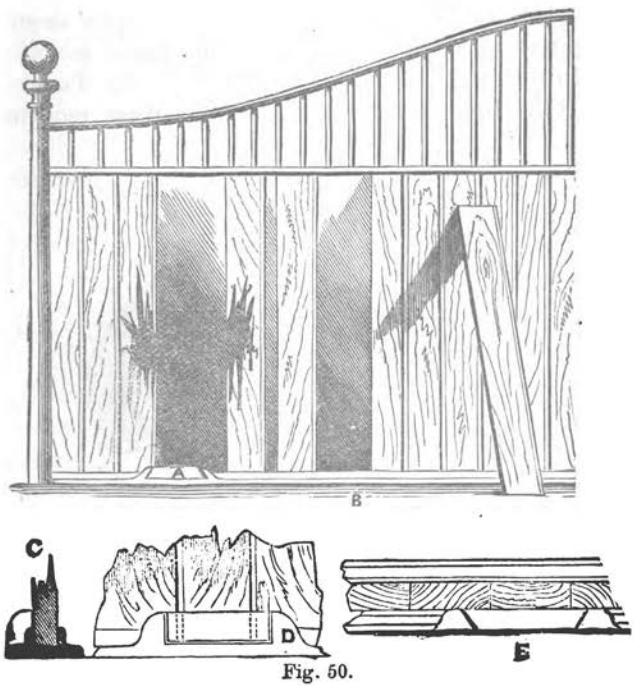


Fig. 50.

placed with the greatest ease. This is shown in Fig. 50.

The engraving shows the elevation of a stall division, consisting of boarding post, ramp, and sill (A the wedge, B the sill), and represents a portion of the boards removed and some fractured ones still left. By merely lifting the wedge, A, out of the sill, B, the boards can be shifted, the broken ones taken out and sound ones put in their place.

C is a section through D of a part elevation. E is a plan showing the wedge.

Loose Box and Stable-door Fastenings.—Fastenings for doors in stables require to be such that a man, but not a horse, however clever, can readily open them; they must also have no projections against which a horse can strike himself. Those of the St. Pancras Ironworks Company thoroughly fulfil these requirements.

The peculiarity of the patent Safety Latch manu-

Fig. 51.

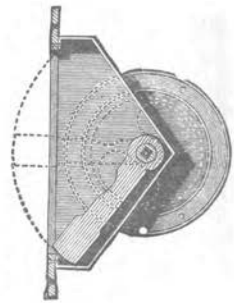


Fig. 52.

factured by the company consists in the mode in which the tongue is made to fall flush into a recess whenever the door is open, so that it is impossible for the tongue to project except when the door is shut. No accident can, therefore, happen to a horse in passing in and out of the box. In Fig. 51 the tongue is projecting, as it does when the door is shut. In Fig. 52 is shown the same latch in section when the door is open, and the dotted line shows the position of the tongue when the door is shut.

Halter-Tying.—The old-fashioned ball and rope passing through a ring on the manger is now seldom used, as the rope soon wears out, the loose swinging ball strikes against and blemishes the horse's knees,

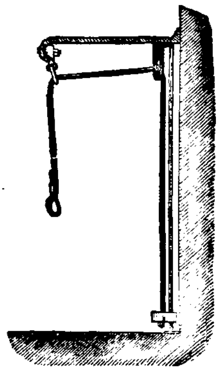


Fig. 53.

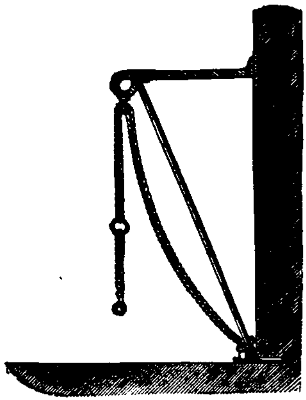


Fig. 54.

and accidents frequently happen from the rope looping up, and so allowing the horse to get his leg over it. The halter-tyings invented and patented by the St. Pancras Ironworks Company are now very generally used in well-fitted stables. The three principal patterns are shown in Figs. 53, 54, and 55.

Fig. 53 consists of a wrought-iron guide-bar with friction-roller, on which a flat leather strap and iron weight work up and down, for fixing under the manger fitting.

Fig. 54 shows a method of tying very generally adopted in cart-horse stables. A strong wrought-iron bar is fixed at the bottom end into the wall or floor, and at the top to the manger. A ring runs up and down this bar, through which a chain, rope, or strap works with a weight attached.

The most improved method of halter-tying, however, is that shown in Fig. 55. It is protected by an

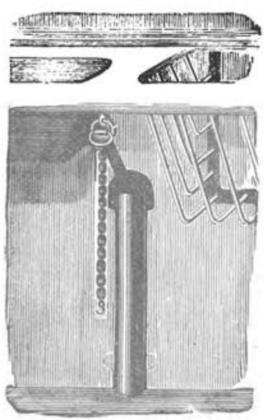


Fig. 55.

iron casing, so that dirt or straw cannot get in; it cannot get out of order; it is perfectly noiseless; the part exposed to the horse is of chain, so that it cannot be gnawed; it is most securely fixed to the wall, and not to the manger; if a horse hangs back he cannot make it stick, but the weight runs back immediately, so that there is no chance of his getting his legs over it.

It is now very usual to have two halter-tyings in each stall. This plan is safer, more convenient, and keeps the horse standing straight.

CHAPTER X.

SHEEP-FOLDS AND SHEDS.

On the majority of farms where sheep-folds and sheep-sheds are in existence, these erections are for the most part detached and scattered. There is no good reason, however, why all the sheep-folds and sheds on any one farm should not form a connected building; and on small farms the sheep buildings may very well be built in connection with the main homestead.

The erections referred to will consist of a lambing-fold and sheds, fatting-sheds or boxes, ram-sheds, field-shelters for lambs and for sheep on turnips, besides a sorting or working-fold. A complete set of sheep buildings must also include a wool-store, a store for sheep-food, and a room for shepherds' tools and utensils. Nor must we forget a shepherd's hut on wheels, so that it can be readily moved to any outlying field or fold where he has to wait attendance on the flock. The hut should be large enough to serve as a lock-up for cake or corn, and it should be provided with a stove, in order that the shepherd may be enabled to prepare warm gruel or milk for ewes or lambs when they require it.

Sheep-fold.—On sheep farms, a permanent fold for working in at sorting times—shearing, weaning, drafting, marking, &c.—is an absolute necessity, and such an erection is a great convenience even on arable farms where sheep are kept. In the absence of a regular sheep-fold, movable hurdles have to do duty, when the flock or any portion of it has to be penned; but in such cases it is seldom that more than one, or at the most two, small pens are formed, and that accommodation is very inadequate for handling more than a score or two of sheep.

The situation of the sheep-fold should be as central

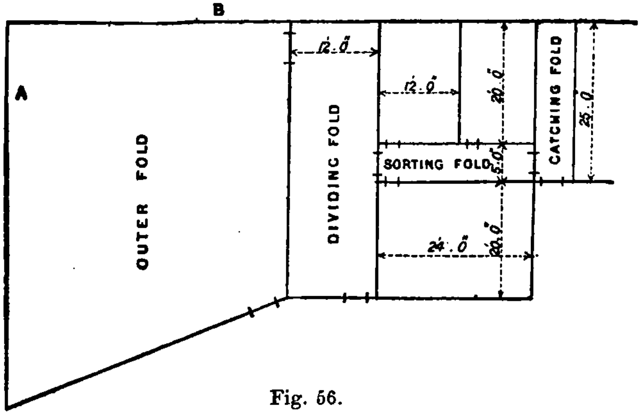


Fig. 56.

as possible, to afford convenience for gathering the sheep from all parts of the farm. It should also be formed on dry ground, and in an airy but not exposed situation.

The size of the outer fold at least should be proportioned to the number of the flock, but the working-folds must not be too large. The arrangements shown in our sketch plan, Fig. 56, will be found to meet almost any requirement.

The outer lines A and B may be stone walls, but the other sides of the enclosure and all the divisions should be constructed of open palings, so as to afford plenty of air to both men and sheep in the fold.

Lambing-fold.—On lowland and arable sheep-farms a lambing-fold of some kind or another is always provided. Sometimes it is a permanent structure, in other cases it is a temporary erection.

The necessary accommodation will be the same in either case, and should consist of a large open fold with shelter-sheds around it, and a second fold, not much smaller than the first, with covered pens on two or more sides. In a permanent fold, a central barn or shed may be erected as a food-store; but for a temporary fold this may be dispensed with.

The amount of shelter required both by ewes and lambs depends not only on the climate of the district, but on the severity of the season, and whether the lambs begin to fall early or not. Ordinary requirements will, as a rule, be fully met if, in addition to the shelter-sheds and open yards, twenty-five single ewe and lamb pens are fitted up for every hundred lambing ewes.

For a temporary lambing-fold we have found the plan sketched in Fig. 57 very convenient. It can be enlarged or otherwise to suit any size flock, and is readily erected by the shepherd himself. It is constructed entirely with thatched hurdles, the pens and shelter-sheds being covered with the same. Previous to the hurdles being put up, the whole of the ground to be occupied by the yards, pens, and sheds should be covered to a depth of 18 in. with burnt clay or good dry mould, this to be kept well littered over with straw when the ewes are brought in. The burnt clay or mould will catch any moisture that the straw fails to take up, and so keep the ewes dry and comfortable;

and when the lambing season is over the burnt clay, which, by that time will be found considerably enriched, forms an admirable compost with the straw and animal droppings which have accumulated on the top of it. Supplies of roots, hay, and straw should also, of course, be stored within the enclosure before the lambing season begins. Sometimes the temporary fold can be erected around an old barn, in which case the straw, hay, and roots, as well as the turnip-slicer or pulper

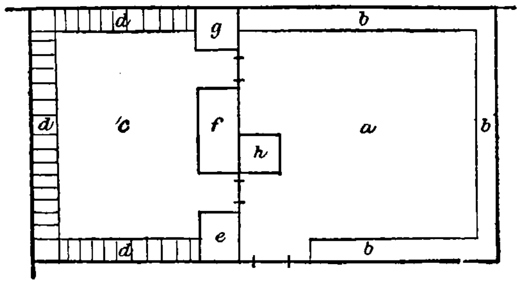


Fig. 57.

a, Yard for unlambed ewes; *b b b*, hurdle sheds; *c*, yard for lambed ewes; *d d d*, covered pens; *e*, straw; *f*, roots; *g*, hay; *h*, shepherd's hut.

and the chaff-cutter, can be kept under cover. The shepherd's hut serves as a store for cake, corn, or meal, &c.; and being fitted with a stove, a supply of warm milk can always be kept ready for any of the lambs that appear to need assistance in that way.

The best position for a lambing-fold is on dry ground, in a situation which is naturally well sheltered, and, if possible, opening into one or more meadows.

Portable Hut for Shepherds.—An illustration of Reeves' Improved Portable Shepherd's Hut is given in Fig. 58. These houses are invaluable to all flock-masters for the use of the shepherds during the lambing season, as well as for storing corn, cake, &c. They are made 12 ft. long, 6 ft. wide, and 6 ft. high to the eaves. The roof being raised, makes it about 7½ ft. high in the middle. The hut is fitted with a good and durable stove, windows in the door, and ventilator. It is made of strong corrugated galvanized iron fixed to a wood frame.

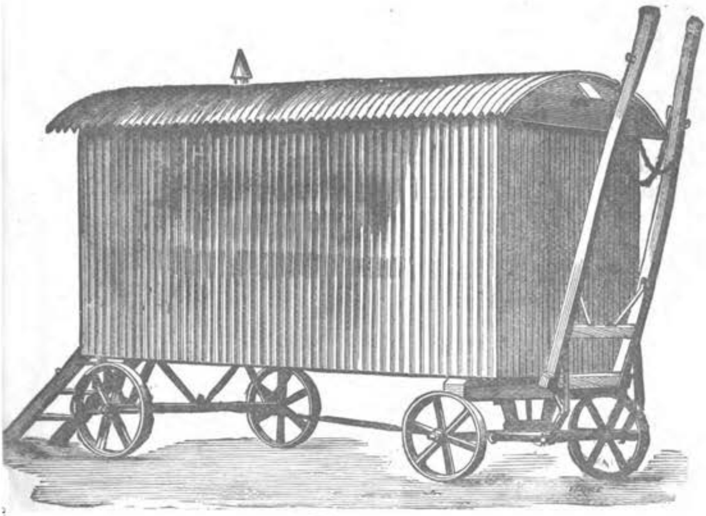


Fig. 58.

The interior is lined with match-board, and the floor is made of good stout boards, tongued with iron. The price complete, fitted with stove, and mounted on four wheels, is £30.

Sheep-shelters.—Something of the kind is indispensable for protecting young lambs both from rain and cold after they have left the lambing-fold. Nothing is more suitable for the purpose than thatched hurdles, or common hurdles covered with waterproof paper or roofing-felt. As a protection from old winds, all that is necessary is to make a close fence of the hurdles, behind which the sheep and lambs shelter. Against rain and snow a few covered shelters can be erected with hurdles. A handy shepherd will erect a rain-proof shelter of this kind in a very few minutes, and a little experience will teach him various ways of doing it. A lean-to hurdle against a side wall or fence will sometimes be the best plan, and at other times a lean-to hurdle on both sides of a hurdle set erect in the open field may be tried. And a third plan is to set up two or more rows of vertical hurdles, the rows four or five feet apart, and lay other hurdles horizontally on the top of them, to form a roof.

We have seen curved sheets of galvanized corrugated iron fixed to wooden bearers used as permanent sheep-shelters with very good effect. They were sent out by T. Pearson & Co. ready to fit together, and rest simply on the wooden bearer, as in Fig. 59. They are made to all sizes, and can be used afterwards on posts as roofs for permanent sheds if desired.

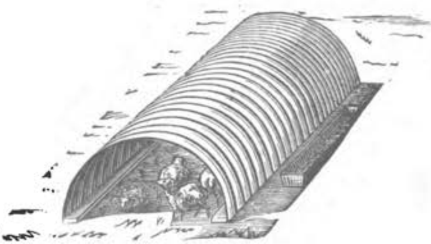


Fig. 59.

Sometimes also, corrugated sheets which have been used as rick-covers are turned to account in forming temporary sheep-shelters of the kind shown in Fig. 60.

One or more of these simple expedients will often be the means of saving the lives of many young lambs in bad weather.

The sheltering of sheep on turnips is also an important consideration, and will well repay any little trouble and expense bestowed on it in severe weather or during long continued wet. It has yet to be proved, in fact, that sheep can be fattened with profit under the adverse conditions of a wet and muddy fold, especially on clay soils, without a dry shelter to lie down under. The provision of the latter is indeed

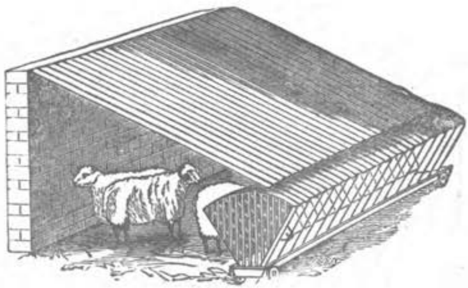


Fig. 60.

only half a remedy in such cases; for the roots, or a portion of them, should be carted off to a dry pasture-field, so that they can be fed there in wet weather. A sheep fatting in the open field will gain 1 to 2 lbs. of flesh weekly in dry weather; while in bad weather it will seldom gain in weight at all, however well it may be fed. The loss which may thus occur in a single week in a large flock of fatting sheep, must often represent a far larger sum than is required to provide artificial shelter for the whole of the sheep.

To winter fatting sheep in the turnip field is bad management, both for the sheep and the land, in any case; but the erection of temporary shelters of thatched hurdles or roofing-sheets will, at all events, prevent the food being entirely wasted in bad weather.

Fatting-sheds.—Sheep do not thrive well in a common straw-yard, but in properly contrived and constructed sheds or boxes they can be fattened with far more speed and economy than is possible out of doors.

A shed 50 ft. × 18 ft., with a feeding passage 4 ft. wide down the centre, affords ample accommodation for one hundred sheep. The shed should be fitted with troughs and racks on each side of the feeding passage, and there should be a food-store and mixing-room adjacent. The floor of the shed should be laid with

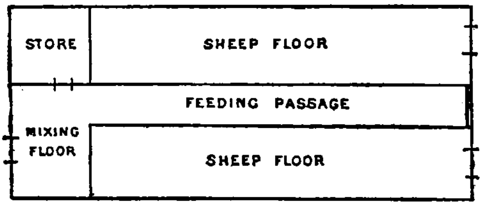


Fig. 61.

asphalte or concrete, and swept twice a day if no litter is used. If litter is to be given, the floor should still be laid with concrete, but the feeding-floors should be 6 to 12 in. below the level of the feeding passage; and sufficient cut straw, sawdust, burnt earth, or good dry mould should be spread over the floors once or twice a day to absorb the urine and moist droppings, and keep the animals healthy and dry. We give a rough sketch of such a shed in Fig. 61.

Sheep-boxes are only advisable where it is wanted to feed a few animals particularly well for the show-yard, or where rams have to be shut up separately. In the former case, each box should be large enough to accommodate five fat sheep or ten lambs, but not more. The space allowed such sheep must be considerably greater than in the large fatting-shed, though it is not well to have the boxes too large. The most convenient size to hold five sheep is, perhaps, 10 ft. square. The floors of the boxes may be constructed in the way mentioned for the floors of the shed, and must be kept thoroughly clean and dry.

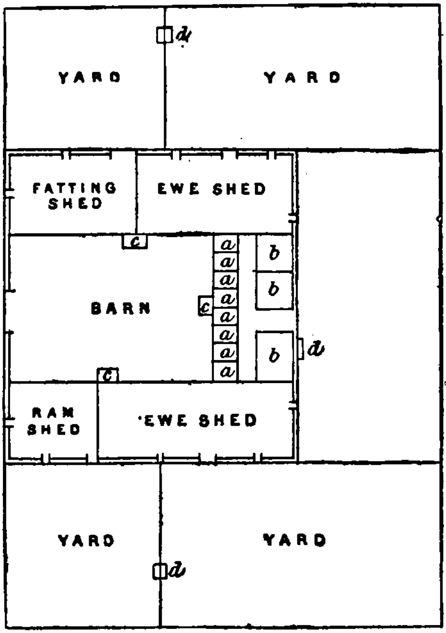


Fig. 62.
a, Pens; *b*, boxes; *c*, corn-bins; *d*, drinking-troughs.

American Sheep-barn.—The ground plan of the American sheep-barn, with yards, is shown in Fig. 62. The covered sheds for the sheep, it will be seen, are built around three sides of the barn, which is convenient for feeding, and there is plenty of yard room on the different sides of the building. Stores for wool, grain, and straw can be built over the sheds if thought desirable.

CHAPTER XI.

PIGGERIES.

It is a common saying that pigs thrive best in the dirt, but that is not true; pure air and a dry bed are essential to their well-being.

Some breeders prefer a double row of sties, with a passage through the middle. "That," remarks Mr. Tommas, "may be very well for going round to see the pigs quickly, but the pigs by that method get too much crowded, the ventilation is bad, and the aspect wrong. If pigs are kept too warm and pampered, they are liable to take cold, which brings on inflammation and fever, which either kills them or causes them to become stunted and not worth rearing."

A useful piggery, erected chiefly in iron, by the St. Pancras Ironworks Company, is shown in Figs. 63 and 64.

The great objection to this piggery is the feeding-troughs being placed in the interior of the house.

The feeding-trough should be outside the sty altogether, as in the section of a piggery shown in Fig. 65.

The feeding troughs are so arranged in the front wall that by raising or lowering a flap door the pigs can be admitted to, or shut off from, the trough at pleasure. The flap doors, when hanging perpendicularly, shut the pigs from the food, but when swung back and fastened

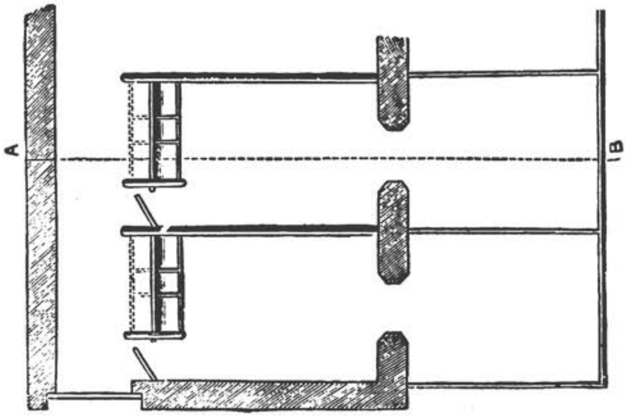


Fig. 63.

by a button to the front of the trough, the pigs are enabled to feed.

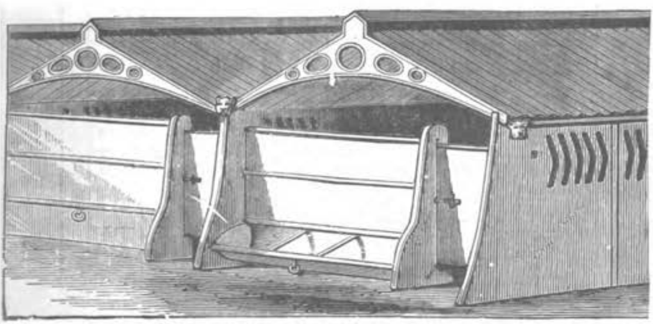


Fig. 64.

There ought in every case to be a passage between the back wall and the interior division, running from end to end of the piggery, so that the covered pen can be kept clean and well littered, and in order that the pigs can be seen when wanted.

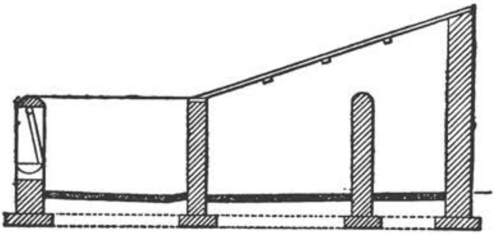


Fig. 65.

Mr. Tommas' Piggeries.—The principal piggery of Mr. Tommas is arranged according to plan, Fig. 66.

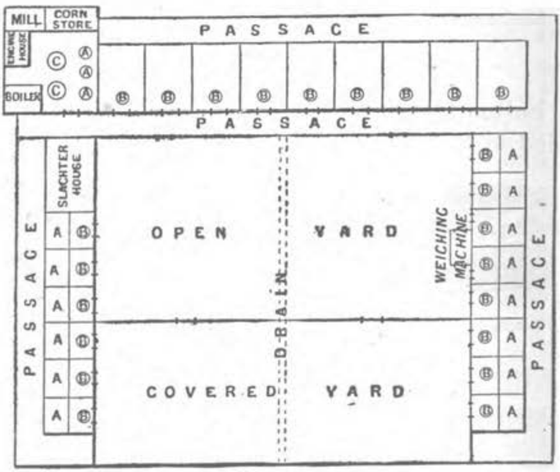


Fig. 66.

A, Movable wooden stages for pigs to lie upon; B, cast-iron feeding troughs; C, mixing-tubs.

The sties are built on three sides of the yard, with the south side open, so that they are sheltered from the cold winds, and the mid-day sun shines into the centre yard. There is a passage all round with sliding ventilators, which are opened or closed according to the weather. The doors in front also have slides.

The materials used in building the sties are brick and timber. The floors are laid with blue bricks, set on edge in cement, so that the water runs off and the floors cannot be rooted up.

For the large breed, Mr. Tommas considers the best size of sty is about 16 ft. by 10 ft., a size suitable for a large sow and family, or for six large ones for feeding or rearing.

About one-half of the sty is raised by a stage made of common planks, on which the litter is spread. In each sty there is a cast-iron trough, about 2 ft. in diameter, of the shape of a saucer, which the pigs cannot upset, and which is easily cleaned.

Mr. Howard's Piggeries.—In the piggeries at Clapham Park Farm, Bedford, of which a plan is shown in Fig. 67, the troughs are in the feeding yards, not in the sties, and each pen of pigs is let out to feed separately.

Writing to the *Journal of the Royal Agricultural Society* on this subject Mr. Howard says: "My piggeries are upon a well-drained site with a southern aspect; they have plenty of fresh air and light, and are distinct from the other premises. Ample provision exists for warmth and shelter in winter. While some persons prefer asphalte flooring on account of cleanliness, the smoothness and hardness are objectionable. Wooden spars absorb urine and accumulate dirt. On the whole I prefer a floor of hard gault bricks laid with cement. At the rear of the piggeries a portion of a field has been fenced off and used as an exercise ground for the breeding sows and other stock pigs.

As it is difficult to provide for yard exercise where a number of stock boars are kept, *they* are placed in sties sufficiently large to give them as much exercise as they need. Boars under nine months old have a regular turn of yard exercise each day. The question of

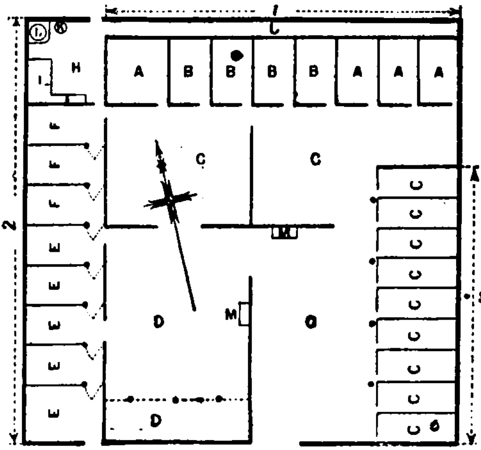


Fig. 67.

A, Farrowing sties.
B, Sties for young pigs.
C, Sties for boars.
D, Shed and yard for sows in pig.
E, Boxes for pigs or calves.
F, Boxes used for farrowing or for sows with litter.
G, Feeding and exercise yards, brick-paved.
H, Boiling-house.
I, Steaming apparatus and flour-bins.
J, Egg-shaped boiler.
K, Copper furnace.
L, Passage.
M, Water-troughs.
Sheds marked 1 and 2 are enclosed.
Sheds marked 3 and 4 are open in front.

exercise for young boars is a very important one, as of course nothing will so much conduce to the development of their legs and feet, which are such important organs in the male animal."

An American Piggery.—In the following plan of an American piggery, the drive-way is 10 ft. wide, and extends the whole length of the shed. A waggon can thus be driven through the shed, when that is more convenient than to run the feed through on a truck. The troughs for the pens extend through the partitions, so as to prevent tipping over. Every alternate trough is used for water. The small pens are for brood sows. The fronts are enclosed with 2-ft. slide gates, so that

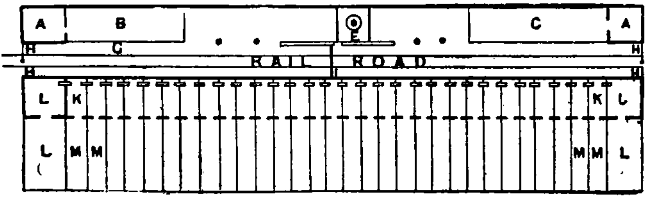


Fig. 68.

A, Cribs, 12′ × 13′
B, Feeding-floor, 13′ × 36′
C, Feeding-floor, 13′ × 40′
D, Large water trough.
E, Well.
F, Gate.
G, Drive way, 10′ wide.
H, Double doors.
J, Pens, 12′ × 13′
K, Pens, 6′ × 13′
L. Open yards, 12′ × 20′
M, Open yards, 6′ × 20′

they can be thrown open to the main shed when the shed is used for fattening hogs. When used for this purpose the shed is divided by the cross-gate (F), and it then affords accommodation for 100 hogs on each side. An Ohio farmer, who built this piggery five years ago, says the whole cost was £70, and that it has repaid him twice over every year.

CHAPTER XII.

POULTRY-HOUSES.

THE general plan of building adopted for poultry is a house and shed with open yard attached. The house and shed may be lean-to buildings, 8 ft. high in front, and are best constructed of wood, except the roof, which should be corrugated iron, as it does not harbour insects, and is always dry. If the roof is a wooden one, the boards should be covered with felt, and the latter kept well tarred.

The details of this arrangement are clearly shown in the plan here annexed of a double poultry-house manufactured by J. J. Thomas & Co., of London (Fig. 69). The open yard or grass run is enclosed with poultry fencing, and can be increased in size to suit any situation.

In Fig. 70 we have the section of an American poultry-house, by Mr. Clarke, showing roosting-poles (*a*), laying-boxes (*b*), and also a method for collecting the droppings. The fowls roost on horizontal poles, their droppings fall on and roll down slanting boards (*c*) into the gutter (*d*), which is made 15 in. wide and 2 in. deep. There is a door, as shown by the dotted lines, with a lid entrance at the bottom, through which the fowls enter at night or in showery or windy weather, taking shelter under the nests, which are 16 to 18 in. wide, and extend the whole length of the building. There is a walk along the gutter, from which the eggs are gathered. A wheelbarrow can be drawn in, when the droppings are taken from the gutter by a shovel. As the hens go in to lay they first spring

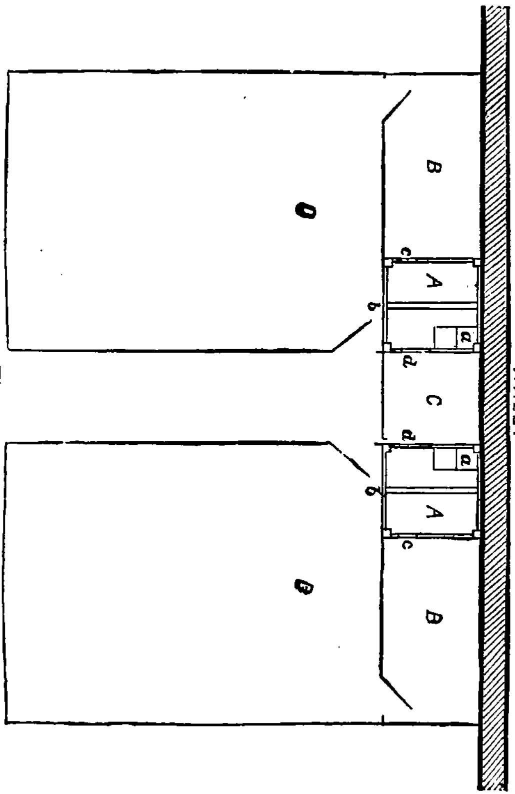


Fig. 69.

A, Roosting and laying houses, with dust-bath underneath.
B, Covered sheds.
C, Hatching house, fattening house, nursery, or chicken run.
D, Grass runs or yards.
a a, Nests with flaps opening into house *C*.
b b, Perches.
c c, Holes for fowls.
dd, Door for attendant.

on to an alighting-board. This is a well-tested plan of a poultry-house, at once simple, effective, and economical.

Those who do not have the roosting-benches now commonly used by poultry breeders, and are opposed to the old style of roosting-poles or strips nailed to the building, may find a swinging roost very convenient, and especially so where foxes and vermin are troublesome. The roost can be made of any length or size to suit the building or the number of fowls. Two hooks are driven into or screwed fast to the side of the building to hold the rings or staples affixed in the ends of the pieces to which the roosting-poles are nailed. A piece of rope is attached at one end by which to raise or lower the roosts. The hook at the end of the rope or wire, which runs from the ceiling, is to hold the roosts either when not in use, or to put the fowls at night above the reach of enemies.

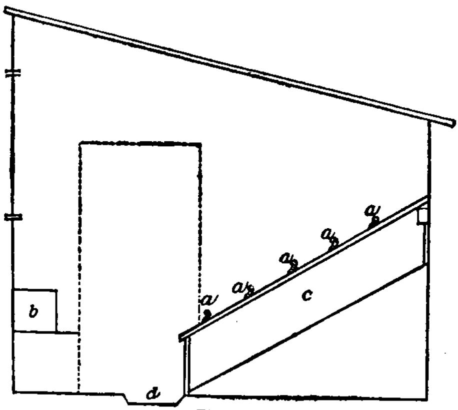


Fig. 70.

Nothing is so good for the flooring of poultry-houses as the natural soil dug up and mixed with screened mortar rubble. If rats are about it is advisable to concrete the floor of roosting-places, but the concrete must be covered deep in screened dusting material of some sort if the birds are to thrive.

The common nesting-boxes are made of wood, and provided with a little straw. They should never be permanently attached to the building, but placed on the floor or hung to the wall. The wooden boxes are however, difficult to keep clean, even when detachable and submitted to a good airing every day. An unclean nest has been proved to be the main cause of hens laying eggs away from home, and is the cause of their laying them about the grounds and frequently dropping them when at roost.

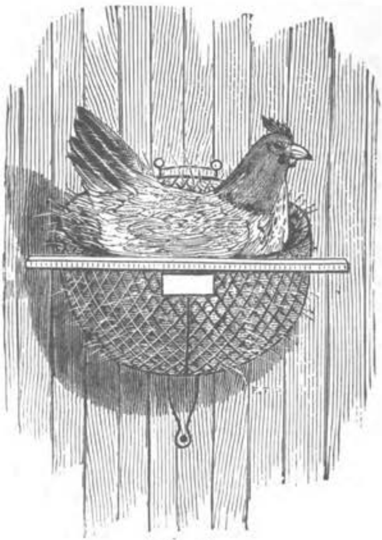


Fig. 71.

Thomas's Portable Sanitary Hen's Nest, illustrated in Fig. 71, is a great improvement on the wooden nesting-boxes. It is made of strong iron wirework, galvanized after making cannot harbour vermin or other offensive matter; can be unhung in a moment for cleansing nests or walls. They will be found exceedingly useful by inverting them and covering over obstreperous sitting hens.

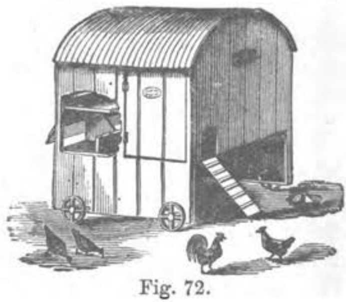


Fig. 72.

A new portable fowl-house on wheels, manufactured by J. J. Thomas & Co., is shown in Fig. 72, and will be found exceedingly useful for pasturing poultry. It is made of wood, painted green outside and lime-whited inside. The roof is of corrugated iron. The floor-boards are loose, and are raised 2 ft. above the ground, which provides a shelter underneath during wet or hot weather. It is fitted with a ventilator and slide to admit air and light when required. It has also a large door for attendant, with lock, and small door with slide for fowls, with door at back, to lock, for removal of eggs. Nest-boxes, perches, and hen-ladder are loose, to facilitate cleaning. It takes to pieces for packing, and is easily put together.

There is great variety in style of chicken-coops, but

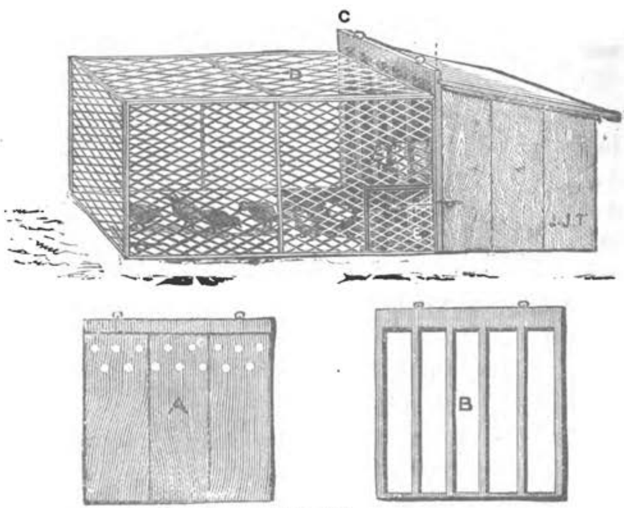


Fig. 73.

Thomas's new chicken-coop and run, which is illustrated in Fig. 73, is one of the best. The coop is made of strong, well-seasoned wood, 2 ft. wide, 2 ft. deep, 2 ft.

high in front, and 18 in. high at back, with a boarded floor. The run is sparrow and vermin-proof, made of $\frac{3}{4}$-in. galvanized wire lattice, 4 ft. long, 2 ft. wide, and 2 ft. high, with a door at the side. It is made to fold flat, and is readily adjusted to the coop by means of hooks or staples.

A, night shutter, which slides into grooves C C, fitted with finger-rings, and has ventilating holes on top for use at night, or, if placed over that part of the run marked D, forms a shelter from sun or rain in daytime. B, cage front, which also slides into grooves C C, and is fitted with finger-rings, for use when it is desirable to confine the hen but give the chickens free run.

Thomas's portable sheds with coops combined (Fig. 74) have an advantage over separate coops, in

Fig. 74.

that the whole of the stock is kept together, which greatly facilitates housing and feeding; while being mounted on wheels, the whole can be readily turned about to suit the sun or wind, or shifted to fresh ground as often as required. In this way several broods can be attended to with little trouble. The sheds are fitted with movable shutters in front to protect the stock from vermin at night. When not in use as coop-sheds the divisions and fronts can be removed; they then form a most convenient shelter for poultry during wet or hot weather, or, if placed near a pond or stream, make an excellent retreat for ducks and other water-fowl.

The sheds are made of wood, well painted outside and lime-whited inside, 6 ft. long, 2 ft. 8 in. high in front, and 3 ft. deep. The fronts are made of iron rods, with a door to each coop. The roofs are covered with corrugated iron.

The illustration represents two sets of coops, one having divided runs.

CHAPTER XIII.

THE DAIRY.

On farms where only a few cows are kept the dairy is generally an apartment in the farm-house, but on large dairy-farms it is a separately constructed building, and should contain at least three rooms on the ground floor. In cheese dairies the cheese rooms may be on the upper floor.

The dairy-house should be placed, if possible, on a porous soil, and sheltered from north and east winds. As a matter of course, it must be kept cool, clean, and well ventilated.

The walls should be thick, and there should be no glass whatever in any of its apertures for light, except for winter use. The window-openings should be narrow but high, and fitted with wire-gauze internally to exclude insects, and with thin canvas blinds outside, which, in very hot weather, may be kept saturated with water. The shade of an elder-tree outside will impart an agreeable coolness, and will also assist to keep out dust. These openings should be screened from the sun; but experience has shown that an entirely northern aspect is undesirable, for the rays of the sun purify the air and assist evaporation. Each opening should have an internal shutter to exclude or temper the light of very bright days, for a subdued light within a dairy is desirable; then a swing-sash, glazed with thick, rough glass, for winter use.

If a one-story building, the roof must be a non-conductor, so as to impart no internal heat. The walls should be covered inside with glazed tiles. The floor is best laid with asphalte or brick, and should incline each way towards a central channel with a trapped grating at the lowest point. For the shelves, marble, slate, thick rough glass, and earthenware slabs are variously employed.

Ice in a dairy should never be necessary. There is always a reaction, and consequently a danger of fermentation if the air within a dairy is brought much below the natural temperature of pure air in the shade. The best *temperature* at which to obtain the largest amount of cream is 60° to 62°, on no account to exceed 65°. This is of great importance to observe. A thermometer, therefore, is an indispensable requisite for a dairy.

the York meeting of the Royal Agricultural Society, 1883, Messrs. T. Bradford & Co. erected a model dairy of temporary material, which was considered suitable in every respect for a butter dairy of about twenty cows. Fig. 75 shows the elevation of this dairy. It comprised four compartments, as will be seen from the ground plan annexed (Fig. 76). First, a porch or entrance room, large enough to hold the

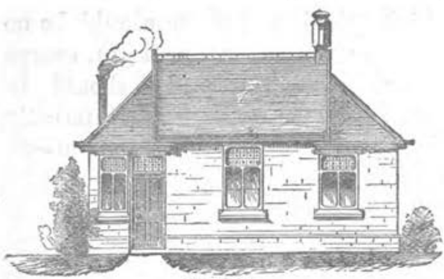


Fig. 75.

churns, pails, &c. Next beyond this the boiler-room, with water-pipes, which not only provided hot water for washing up, and pipes for warming the milk-room in winter time, but also materially assisted in ventilation by warming the air in the ventilating shaft. These two rooms form one division of the building. Next is the working compartment, and beyond that is the milk-

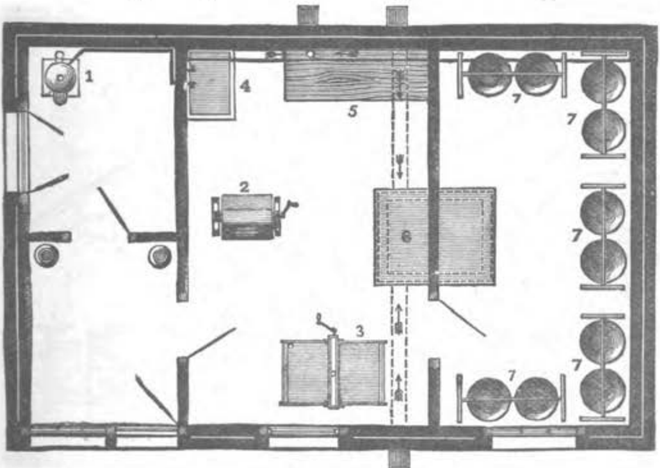


Fig. 76.

1, Boiler and hot water cistern.
2, "Diaphragm" churn.
3, "Albany" butter worker.
4, Washing trough.
5, Table.
6, Ventilating chamber, with slate top.
7, Revolving-disc milk-pan stands.

room. The two last are about similar in size, 10 ft. × 16 ft. The floors are paved with red and black tiles laid in concrete. The whole material necessary for a dairy of 20 cows, where the skim milk is consumed by calves and pigs, costs about £32, to which must be added £20 for the circulating boiler, piping, &c.

The dairy is built up to dado height with white glazed bricks, as seen in section (Fig. 77), and shows a hollow-wall structure, fitted with milk-pan stands, &c., and a ventilating chamber of brick in the centre, with slate top, which gives admission to fresh air, being connected by three air-pipes with the outer air. The roof is of simple span construction, boarded to the collar; and rising from the centre, with its openings arranged

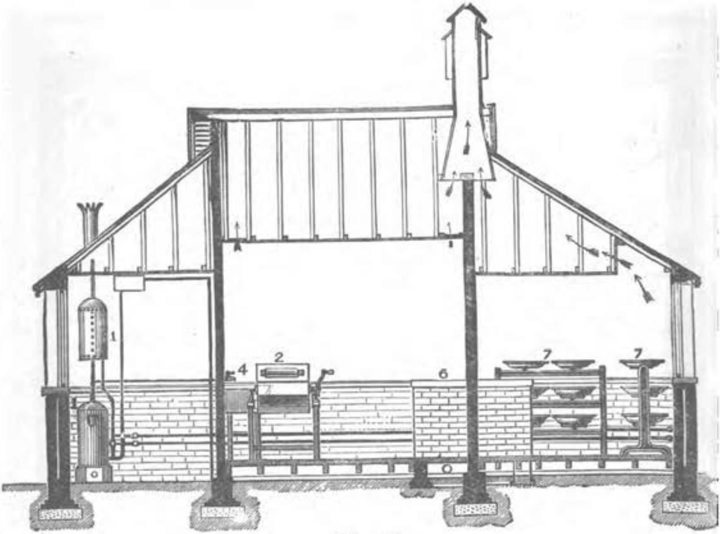


Fig. 77.

on each side of the centre cross wall, is a ventilating shaft fitted with Bradford's "Walness" cowl. The churning-room floor is of concrete, and that of the milk room is laid with red and blue tiles. There are no shelves upon the walls, the old plan of setting all round a dairy being abandoned in favour of revolving milk-pan stands of three tiers, which is a convenient and economical arrangement for skimming the milk. The space occupied by the pans is thus small compared with other arrangements, and stands and walls can be more easily kept clean.

CHAPTER XIV.

MISCELLANEOUS BUILDINGS.

THERE are a number of building compartments in a complete homestead not yet noticed, and which need only be mentioned here.

Engine-house.—A small separate room should always be appropriated for the steam-engine, wherever one is used, and there are few stock and arable farms that can now do without a small engine for grinding, pulping, and chaff-cutting, even when other power is employed for the heavier work of threshing. The engine-house is most conveniently situated at the back of the threshing barn, from which a shaft can be carried to the grinding, pulping, and chaff-cutting rooms.

Cart and Implement Shed.—These should be given a northern aspect, and if there is no loft or granary to be built over them, they may be lean-to sheds of cheap construction. No steading is complete unless it provides a covered building for all carts or other vehicles, and for all tools, implements, or machines used on the farm, as the capital invested in such equipment, and the cost of keeping them all in repair, is now a very serious item in farm accounts. The effective working of many of the most expensives machines—such as reaping-machines and ploughing-engines — is often destroyed by want of this accommodation, and even the commonest implements suffer from out-door exposure when not in use.

The cart-shed should be wide enough to admit of all the shaft points being completely under cover. The back wall may be fitted with brackets on which the ladders not in use can be suspended. If there are no hay or grain-sheds in the rick-yard, it is well to have the cart-shed, or part of it, lofty enough to receive a cart or waggon loaded with hay when rain happens to fall before its contents can be transferred to the rick.

At one end of the implement-shed there should be a lock-up compartment for small tools and extra gearing, such as plough fittings, reaper or chaff-cutter knives or blades, cart ropes, &c.

Smith and Carpenter's Shop.—On large farms a smith's forge and a wheelwright's or carpenter's shop will be found a great advantage and economy. The great loss of time and heavy expense in shoeing horses, repairing plough-irons, and doing the smith's work of the farm elsewhere, fully justifies their erection. Something is always giving way or wearing out, and with renewings and mendings the smith need seldom be unemployed in this way. When there is no smith's work to be done, he can turn to farm work of some kind until wanted at the smithy again.

The wheelwright should do all the carpenters' work on the farm, keeping all the woodwork of the buildings as well as carts, waggons, and agricultural implements in good repair, also painting them at proper times. Should any leisure time occur, the blacksmith and himself can have a new cart or waggon in the course of construction.

Manure-house.—If much artificial manure be used on the farm, there should be a separate apartment for storing, mixing, and measuring it. The manure-house should have a hard floor of asphalte or cement, and be provided with scales, weights, and measures.

Dung-pits for farmyard manure, and likewise liquid manure tanks, disappear as fast as covered yards are adopted. If buildings are constructed and arranged on the modern and improved system, dung-pits and manure-tanks are worse than useless. The farm-yard manure is best made and preserved in the covered yards and boxes. All the stables, cow-houses, feeding-stalls, and piggeries should therefore be arranged so that the dung from them, including the drainings, can be shot into the covered yards, where it should be spread daily and left to be trampled under the cattle until such time as it can be carted direct upon the fields.

Other buildings.—Amongst other buildings which may be more or less necessary are root-stores, tool house, weighing-shed, wool-store, slaughter-house, chaise-house, mess-room for labourers, and kilns for burning lime and drain-pipes, and for drying hops, malt, corn, &c. The mere enumeration of these must, however, for the present, suffice.

CHAPTER XV.

FARMHOUSES.

The farmer's dwelling is frequently built attached to the homestead, on small farms at least. It is better in general, however, to have the farmhouse a little distance away from the farmyard. At the same time inconvenience may arise if the distance between the two is more than a hundred yards or so, and it is well, if possible, to have the house so placed that the yards are within view from the windows of the farmhouse.

Site and Aspect.—It is a matter of great importance to select a good site for building on. Soils which are stiff and clayey do not allow the water to flow freely through them, and are for the greater part of the year damp. Unless proper precautions are taken, the damp air from such soils ascends into the house and often produces disease, more especially rheumatism and diseases of the breathing organs. Light, easily-drained soils are the best sites for dwellings. Hollow, low-lying ground, and the banks of sluggish streams, are bad sites, whilst good ones are to be found on the crests or slopes of hills and eminences. Trees in the neighbourhood are useful, but they should not be close to the house. A south-east is the best aspect. "It is better to let carpets fade than to exclude sunlight."

Accommodation.—In size and accommodation the farmhouse ought to be proportioned to the capital employed in the farm. No farm ought to be so small, however, that it will not afford a house something above a labourer's cottage. The farmhouse should contain at least three or four sleeping apartments, two parlours or sitting-rooms, a commodious kitchen, scullery, larder, pantry, and a dairy or milk-room, besides such necessaries as coal or wood-house, ash-pit, &c. One or more indoor water-closets should always be provided, and in the better class of farmhouses a bath-room as well. The necessary difference in the accommodation afforded by small and large farmhouses consists more in the number of bedrooms and in the size and finish of the various apartments than anything else. On large farms, however, the house may very well have an extra sitting-room, and also a small office where the farmer can pay his men and transact other business without intruding on the domestic arrangements. Of course some of the accommodations necessary to a farmhouse vary with the district in which it is situate. In some of the southern counties, for instance, an apple-chamber, a brew-house, and an underground cellar may all be indispensable; while in most of the northern counties they would not be wanted. All houses should have ample closet accommodation for linen, china, &c. The entrance hall should form a comfortable apartment in the farmhouse, and not be a mere passage leading to the staircase, with side doors opening into the sitting rooms, as is too frequently the case.

Farmhouses need never be more than two stories in height, and an underground story should be avoided, except for cool cellarage. Three or more floors and underground stories are necessary evils in crowded town houses. It savours of imbecility to ape them in the country.

The Hall should be in the centre of the house, so as to afford ready access to the different rooms, and spare the necessity of passing through one room into another. Its size should be proportionate to the space afforded for the whole house. When capable of being so arranged that no external doors or windows open directly into it, the hall may be a most important aid to the warmth and healthful ventilation of the rooms connecting with it, and on this account somewhat more space may be given to it than the dimensions of the rooms would seem to require. It should have free ingress of pure external air for summer use, and be capable of comfortable warming in cold weather. Then, when a door opens, fresh air accompanies the act; whilst in winter time the draught is not felt because the temperature within and without the rooms corresponds. In a hall of any size a cheerful fireplace is indispensable. Pictures, plants, and bright and cheerful objects of art are fitly arranged in a hall, the light of which being often from above, may be made peculiarly suitable for their display.

The Staircase should never seem to lead directly from the front door; in even the smallest house it may be screened by an inner partition, and in all plans the ascending flight may be placed upon the sheltered side, so that, on coming in, the direct communication with the upper floor may not be seen.

The height and width of a step affect the comfort of the ascent of the stair; frequently a shallow step is found more tiring than one of steeper rise; 6¾ in. rise, with 12 in. for the tread, will give a comfortable and convenient stair; but if the space will not permit so much as 12 in. for each step, and 10½ or 11 in. be compulsory, then the rise must be increased to 7 in., or even $7\frac{1}{8}$ in.

A useful rule is, that the rise and tread added together should represent the proportion of 7 and 11, which is, as Professor Kerr says, "the ascertained standard of ordinary stairs," so that a rise of 6 in. would require 12 in. for the tread; one of 5 in., 13 in., and so on.

The direct line of ascent of a long stairway should be broken to secure ease. One continuous flight is tiresome, and of unpleasant appearance.

The Bedrooms are best situated upstairs, as when so placed they are healthier; and it is a curious circumstance that the air close to the ground is always colder at night than the air higher up. The sleeping apartments should also be spacious. Pure air is more necessary at night than at any other time, and can only be enjoyed in a room of good size. 3,000 cubic ft. is the smallest breathing space that should be permitted for a sleeping room for two persons, and that would be contained in a room about 14 ft. × 16 ft. and 10 ft. high. The space in such a room should not be lessened by large pieces of solid furniture.

The Dining-room should be near or on the same side of the house as the kitchen; and the passage connecting the two should be so shut off as to prevent either the necessity of crossing the main hall with dishes, or the exposure of the domestic economy to visitors or guests.

The Kitchen should be large, well-lighted and ventilated, with windows opening close up to the ceiling.

The Larder should be in the vicinity of the kitchen, but removed from fireplaces, chimney-flues, and wash-houses, and should not be too light. To secure a perfect arrangement, its door should open into an entry with a second door, so that the danger of heated air finding entrance may be diminished. Its first quality is coolness. It ought, therefore, to have an aspect either north, or removed from the south or west. It should be sheltered outside by trees from the sun, and it should have a free current of air through it.

The walls should be thick, and it would be well to have them double, with a space between. Tiles or slate form the best lining for the inner walls. The floor may be of hard concrete or cement, or laid with bricks or flagstones. The ceiling under the roof, if of one story, should have an air space above it, and should be frequently whitewashed.

The window apertures should be rather numerous than large, and should be fitted with metallic gauze for ventilation. In hot or "muggy" weather, cotton cloth hung inside the windows, and kept constantly moistened, will materially assist in lowering the temperature.

Dampness and over-dryness must alike be avoided. Whilst not forbidding a soft, cool moistness in the air of a larder, the floors and walls must be absolutely dry and non-absorbent. Frequent wiping of the walls, shelves, and floor is necessary to remove the exhalations from meat and cooked food, which, owing to the lower temperature of the walls, will collect in considerable quantity.

House Drainage.—All drains should, if possible, be laid outside the house, but if this is impracticable, the drains under the house should be embedded in concrete at least 6 in. thick. All joints should be water-tight and socketed, and if the drain is for conveying sewage, should be formed with Portland cement. All pipes intended for conveying sewage ought to be of not less diameter than 4 in. internal measurement, and should be glazed and perfectly smooth inside; otherwise deposits will occur, and eventually stop the drain. No direct inlet should be made (except for a water-closet) within a building to a sewer or drain, but a drain should be constructed to a point outside the house, and there between it and the drain to the sewer should be placed a proper disconnecting trap, open to the external air, so as to prevent sewer-gas entering the building. The soil-pipe of all water-closets should be carried outside the house, and be continued upward without diminution of diameter, and, if possible, without any bend or angle being formed in such continuation of soil-pipe, to a height and in such position as to afford, by means of the open end, a safe outlet for sewer-air. This soil-pipe should have no trap between it and the drains, or in any part of it, except that necessary for the water-closet apparatus, thus forming a ventilator for the drains. In addition to the soil-pipe continuation upwards, at the head of the drains should be fixed a ventilating-shaft of the diameter of the drain at that point, and continued upward the same as the soil-pipe. All waste-pipes from baths, sinks, lavatories, and overflows from cisterns, safes under baths, and water-closets, or any pipe intended to carry off waste water, should be constructed so as to discharge in the open air over a trapped gully grating. If this cannot be done, the waste-pipe itself must be trapped to prevent the ascent of foul air. The trap consists of a bend in the pipe, which, of course, always retains a certain quantity of water, which stops the upward course of the air at the point where the water stands in the pipe. There should also be an escape for the foul air furnished, by which it is carried up through the roof of the building.

Kent.—Our first illustration of a farmer's dwelling is

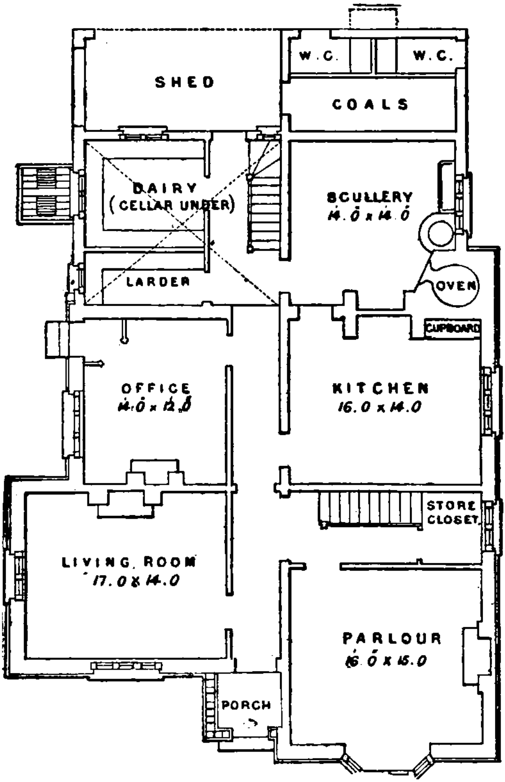


Fig. 78.

the plan of a house recently built on a farm near to Wye, Kent. This farm consists of 206 acs. of productive land: 160 acs. arable, including a few acres of hops, the remainder pasture. The new house is of brick with a plain tile roof. The contract amount was £930. There is no special feature in this house, but it is generally admitted to be a convenient one. Fig. 78

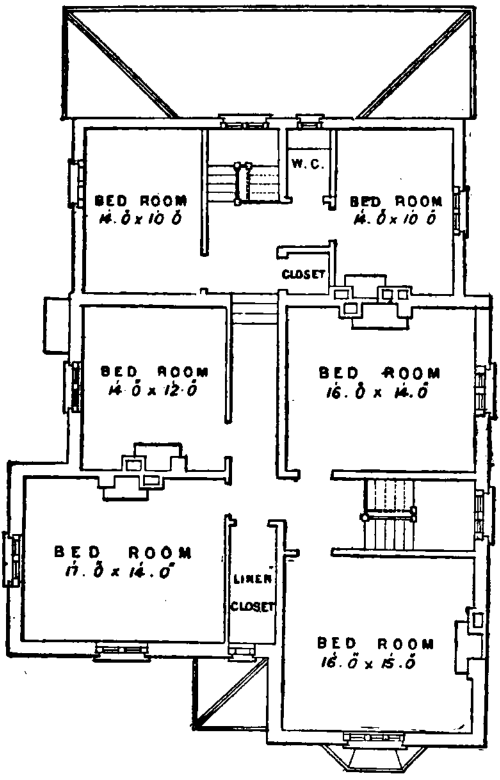


Fig. 79.

shows the ground plan, and Fig. 79 the chamber plan. The design is by Messrs. Bailey Denton, Son, & North, to whom we are indebted for the use of the plans.

Cheshire.—As an example of a convenient house for a moderate-sized dairy farm, we give in Figs. 80 to 84 drawings of one recently erected on a farm of the kind near to Audlem, Cheshire. The extent of this farm slightlv exceeds 200 acs., of which 150 acs. are pasture,

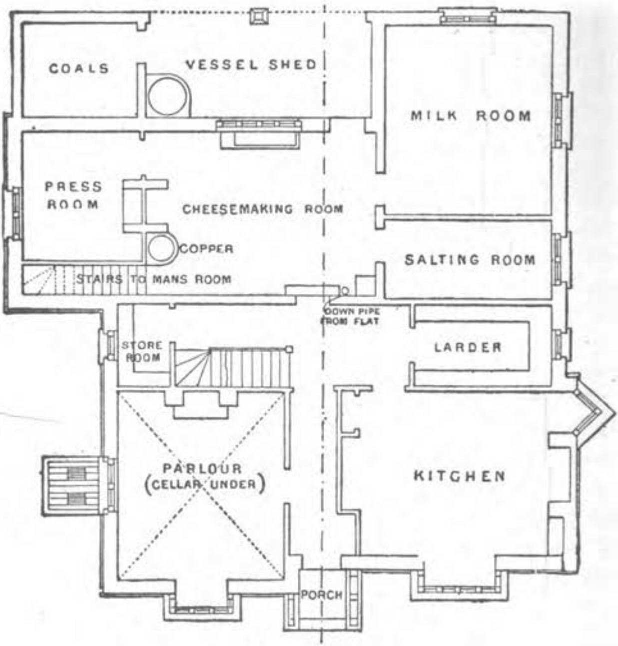


Fig. 80.

carrying a herd of about forty dairy cows for cheese-making, and the remainder is arable, largely devoted to the growth of potatoes. The house is built of brick, with a slate roof. Fig. 80 is the ground plan; Figs. 81 and 82 chamber plans; Fig. 83 front elevation; and Fig. 84 is a section through Fig. 80. The contract amount was £895. This plan was submitted to con-

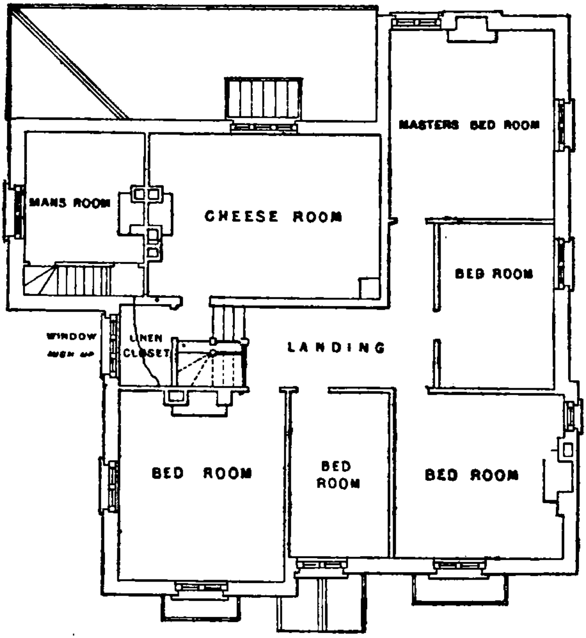


Fig. 81.

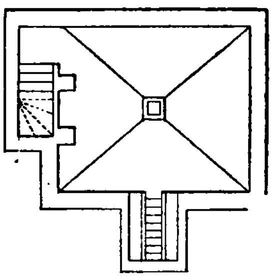


Fig. 82.

siderable criticism before it was finally adopted. It is the design of Messrs. Bailey Denton, Son, & North,

Fig. 83.

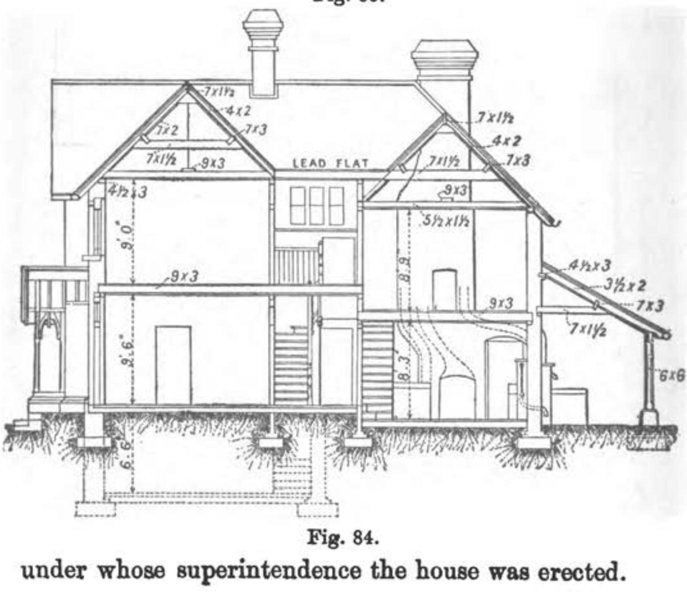


Fig. 84.

under whose superintendence the house was erected.

Selkirkshire.—Our next example is a farmhouse on the

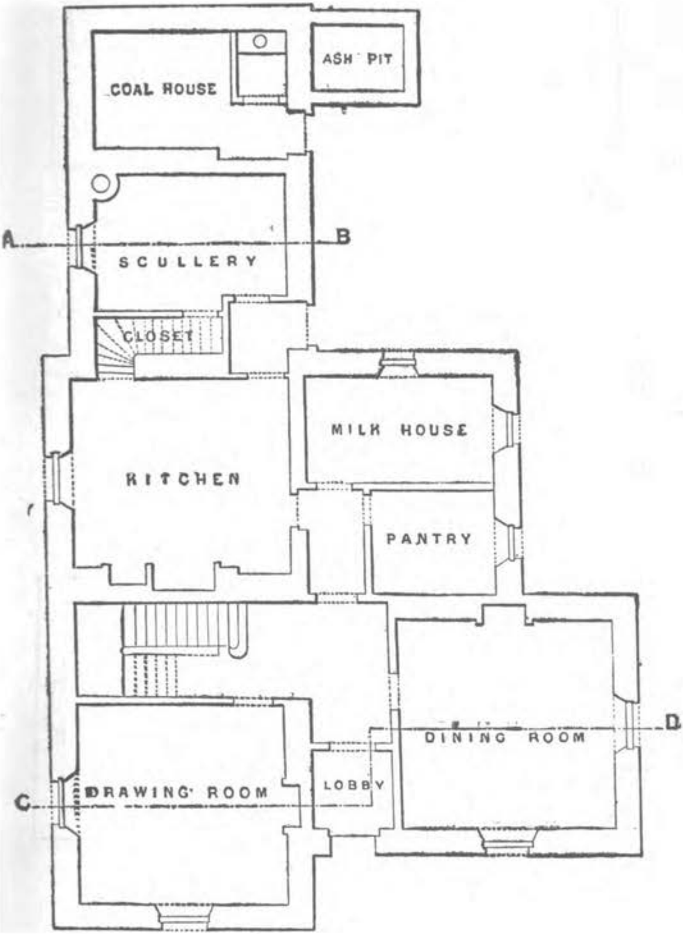


Fig. 85.

Selkirkshire estate of his Grace the Duke of Buccleuch.

The farm is a mixed one, with about 200 acs. of arable

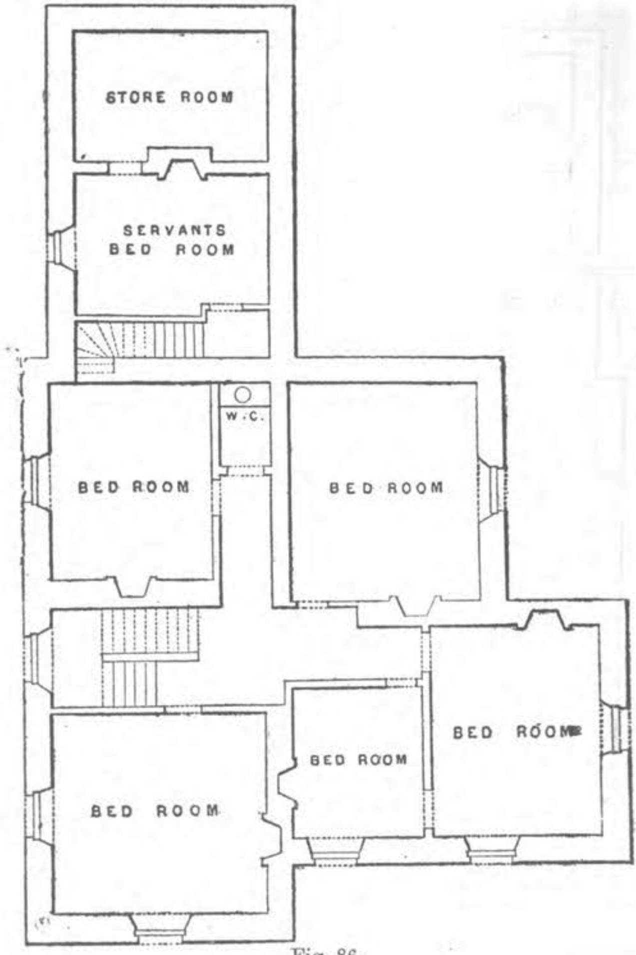


Fig. 86.

land, and hill pasture to carry 2,000 sheep. The house is built of stone, with a slate roof, and was designed by the late Mr. Cowan. Fig. 85 shows the ground plan; Fig. 86, chamber plan; Fig. 87, section on the line

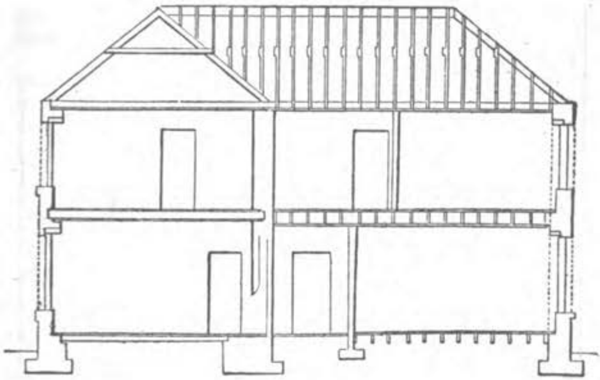


Fig. 87.

C D; and Fig. 88, section on line A B. Cartage was done by the tenant at his own cost. The contract amount, exclusive of cartage, was £950.

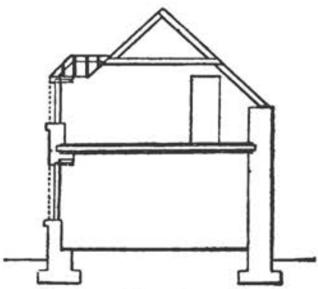


Fig. 88.

This house is well and substantially built, and makes a comfortable and convenient dwelling for the district in which it is situate.

Roxburghshire.—Fig. 89 is the ground plan of a

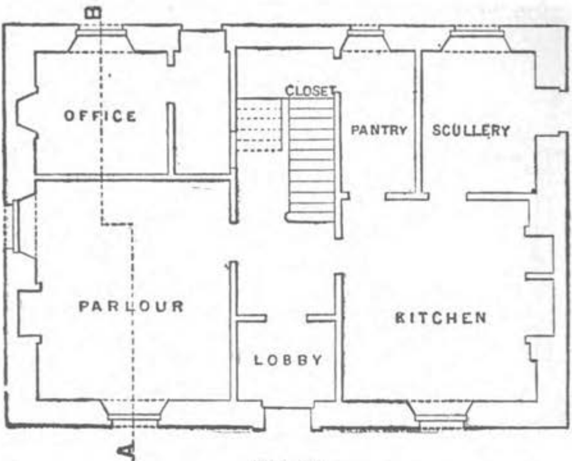


Fig. 89.

house on a small arable farm in Roxburghshire, also on

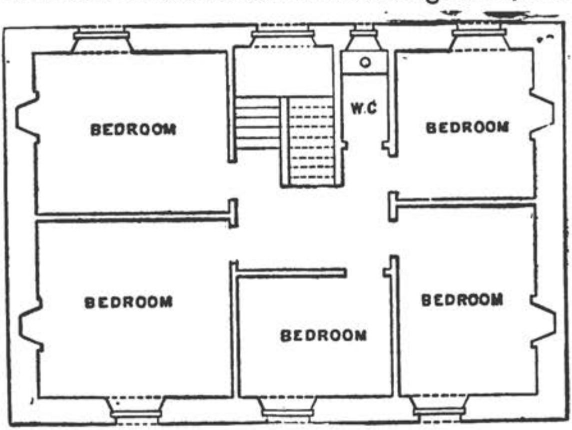


Fig. 90.

the estate of the Duke of Buccleuch. The farm contains about 75 acs. arable, and 25 acs. or thereabouts of meadow pasture, and is chiefly devoted to cowkeeping and the sale of new milk, for which there is

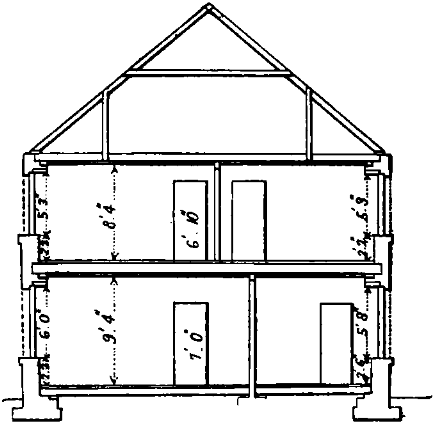


Fig. 91.

always a brisk demand at the dairy, it being surrounded by a large town population.

The house is built of stone, with a slate roof. Fig. 90 shows the chamber plan; and Fig. 91 a section on line A B. The contract amount was £690, the tenant doing most of the haulage.

CHAPTER XVI.

COTTAGES.

No farm can be considered fully equipped without a full complement of cottages. The acreage of the farm is no guide to the requirements in this respect, because everything depends on the system of husbandry pursued, and on the surrounding population. It is necessary, however, that cottage accommodation should be provided for all stock-keepers and ploughmen. Thus there should be a cottage for every full team, as also for the cowman, the shepherd, &c. On large farms it is also requisite that there should be a house for a working bailiff or steward; and if there is no village near to the farm, several extra cottages may be required, in order to insure the necessary force of labourers.

All the cottages, except the shepherd's, which on some farms may have to be outlying, should be built within convenient distance of the homestead, on high and dry ground adjoining a hard road, and, if possible, beside a spring or running brook. Where there is more than one cottage on a farm they may be built in pairs, or in blocks of four or more.

The number of rooms in farm cottages need never exceed five, but they may often be fewer. A single cottage should not be built with fewer than three bedrooms, in addition to a living-room, scullery, pantry or larder, and the needful out-houses. In a double cottage, however, it will, as a rule, suffice if one of the houses has three bedrooms and the other two; and in blocks of four houses it will be found that, taking all ages of married couples, the following arrangements will meet the general wants: one cottage, one bedroom; two cottages, two bedrooms; and one cottage, three bedrooms.

The living-room should have a superficial area of not less than 150 ft., and the height of ceiling 8 ft. It is desirable that there should be a porch to this living-room, and that such porch should have a door. The fireplace should be fitted up with a grate and oven attached. The window or windows of the room should face the south, east, or west, and one third or one half of such windows should open, especially the upper half. A due south aspect, as compared with one due north, will make two months' difference in firing in the year. The floor should be laid with wood, either wood pavement upon concrete, or deal boards upon joists with sleeper walls, and ventilating bricks in the side wall.

The scullery should be fitted with a sink and copper, and have a door opening to the outside, without passing through the living-room. If the floor is of brick or stone-flag it should be laid upon concrete; but it will be equally serviceable if constructed wholly of concrete or asphalte cement. The sink should connect with a drain not discharging into a privy, but taken to some safe distance from the house, and be properly trapped; and it is desirable, in addition to the trap, that the communication be broken outside the house.

The pantry should have a free passage of air through it, with a window or opening facing north or east, and it should be fitted up with two or more rows of shelves

The bedrooms should all be ceiled, and partitions between bedrooms should extend from the floor to the ceiling. To each bedroom there should be both a door and a window. If there is no fireplace, an opening, either into the ceiling or else into the staircase should be provided for ventilation. When there are two bedrooms, one at least should have a fireplace; if there are three rooms two should have fireplaces. The parents' bedroom should have a cubic contents of not less than 900 ft., the boys' bedroom not less than 700 ft., and the girls' bedroom not less than 600 ft. All the bedroom floors should be of wood, and if upon the ground floor the wood should be laid upon sleeper walls or concrete. All the bedroom windows should be made to open.

Where there is a staircase window it also should be made to open. When there is no staircase window a ventilator may open through the ceiling into the space under the roof. The staircase should not be less in width than 2½ ft., with a breadth of step 9 in., and a maximum rise, each step, of 9 in.

Every cottage should be provided with a water or earth-closet or privy, such privy, when dry, not to be nearer a living-room than 20 yds., and connected with an impervious system of drainage, or have an impervious iron pan or cess-pit; and there should be no leakage into the subsoil. If a water-closet is attached to the house it is essential that it should be on an outside wall. Many objections are urged against providing cottages with water-closets, but the objections are for the most part valueless. The cost is less if it is placed inside than if placed outside the house, and if the closet is properly fitted in the first instance there will be no difficulty about the inmates maintaining it in good order. When a water-closet is situated inside the dwelling the occupants have a greater interest in keeping it in an efficient state. Whether a water-closet or a privy is provided, it should have an external opening or window not less than 1 ft. superficial, and made to open.

The coal and wood house and the ash-pit are best placed in the back-yard. The pig-stye, if any, may be immediately behind them.

The back-yard and all front and side walks should be laid with asphalte, or paved or gravelled.

All the roof water should be collected in a tank or cistern, and if storage water is relied upon for a supply the minimum that should be provided for is 5 gals. per head per day for eight weeks.

The cost of building cottages will vary with the amount of accommodation provided, with the material employed, and with the class of workmanship. At the present time a brick or stone-built cottage with one bedroom and other necessary apartments, will cost from £75 to £100, according to district, &c.; and a cottage with three bedrooms, &c., from £124 to £150.

The condition of farm cottages has wonderfully improved within recent years, especially on the larger estates, both in England and Scotland, and that not merely in the matter of accommodation, but also in their sanitary surroundings. Still, in neither of these respects are workmen's cottages in the country all that could be desired. Hence diphtheria and typhoid fever are harboured amid scenes where they really ought never to exist.

And how comes it that the cottage homes in the south are always bright, cheerful, and picturesque-looking, while those in the north, as a rule, present little more than bare walls to the eyes of the passer-by? The difference is not altogether due to climate, for with equal taste and love of the beautiful, the occupier of a cottage in the north may, with the help of a few shrubs and flowers, a neat garden entrance, a few wall fruit-trees, and the application of a little fresh paint to walls, fences, and gate, make the exterior of his dwelling as bright-looking as that of his neighbour in the south, with its trellis vine, and other plants and flowers of more genial growth. This is one of those things, however, that require to be pointed out to the cottager, and in which not much will be done until both the proprietor himself and the farmer help to encourage and promote it.

Each cottage should have a garden of about a rood in extent, which is large enough to supply the family with vegetables, and not too large for the cottager himself to cultivate without spending the strength which should be reserved for his more especial employment.

In addition to this small garden, however, every country cottage ought to have a little orchard of fruit-trees. Far beyond the present limits of apple and pear cultivation, a portion of the cottage garden might with much benefit be set apart for this purpose. Besides being a source of enjoyment and profit, the orchard has other recommendations, for it provides shelter and ornament—two things very essential to the comfort of a dwelling in many of the localities where orchard culture has yet to be introduced.

Stone-built Cottages.—In illustration of such we present the plans and particulars of some Northumberland cottages recently erected. They are four-roomed cottages, fitted with pantries, &c., and finished in a very substantial and suitable style. Each cottage has its own back-yard quite secluded from the adjoining yards, and the outhouses abut upon a lane, giving access for cartage.

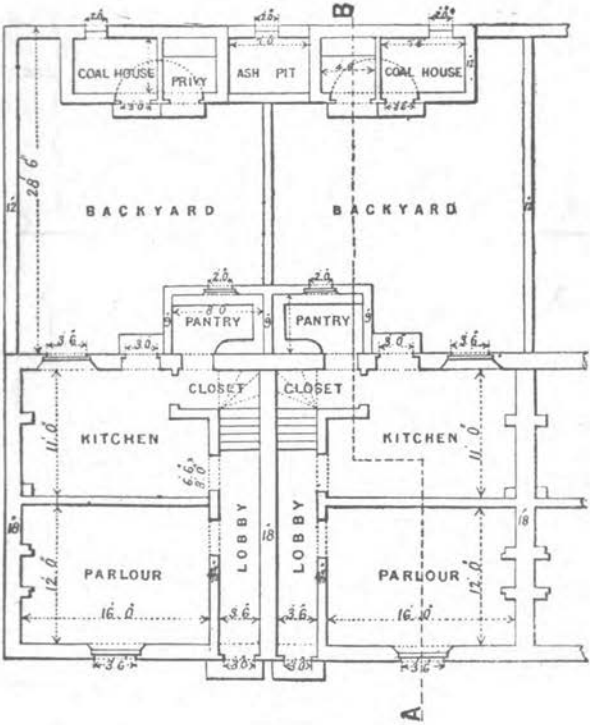


Fig. 92.

Fig. 92 shows the ground plan; Fig. 93 chamber plan; Fig. 94 front elevation; Fig. 95 back elevation; and Fig. 96 section through A B.

The actual cost of these cottages was from £124 to

£138 each. For specification of works and measurement of one cottage, see Appendix, pp. 148 and 162.

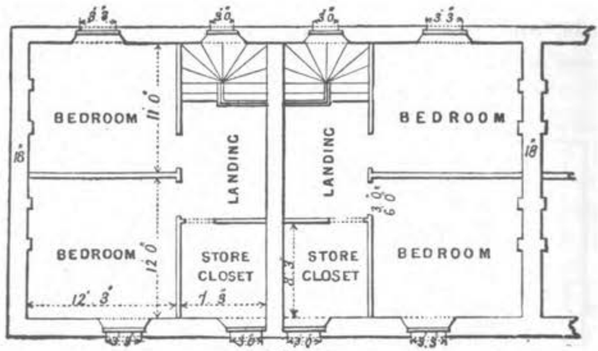


Fig. 93.

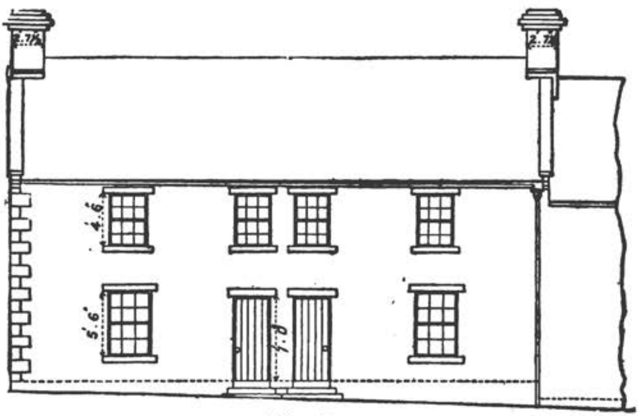


Fig. 94.

On a Durham estate the contractor's prices for sixteen new cottages, built of stone, are as follows:—

Four 2-roomed cottages at £85 complete each.
Six 3-roomed cottages at £104 „
Four 4-roomed cottages at £125 „
Two 5-roomed cottages at £135 „

These cottages also are of substantial construction and well-finished workmanship.

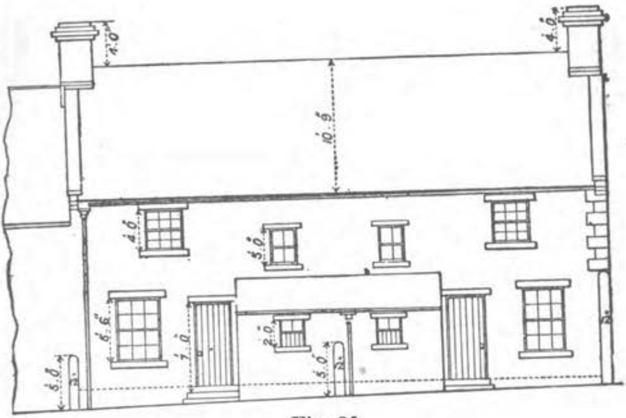


Fig. 95.

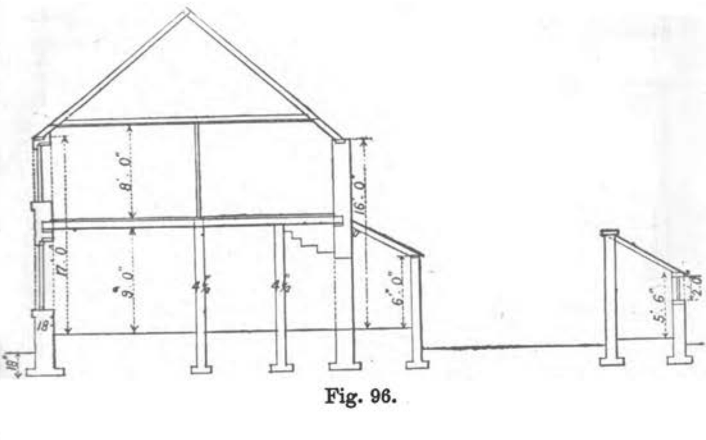


Fig. 96.

Inferior houses can be erected at a considerable reduction on the above figures.

Brick Cottages.—Cottages built entirely of bricks and timber can be erected at a less cost than the foregoing. A number of brick cottages, each containing

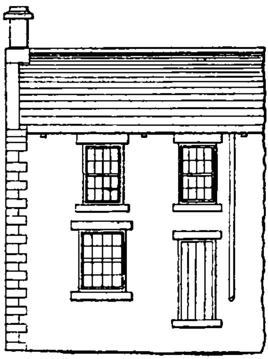


Fig. 97.

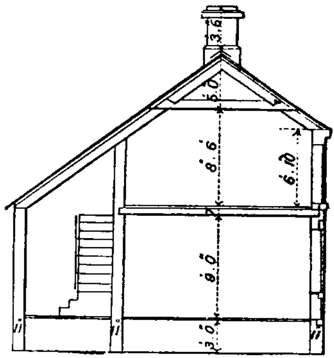


Fig. 98.

three rooms besides pantry and scullery, with ash-pits and privies at the back, were lately erected on a North-

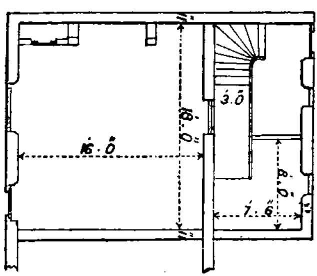


Fig. 99.

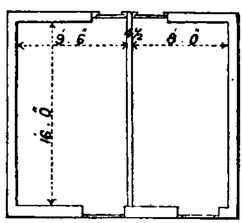


Fig. 100

umberland estate at a cost of £75 5s. each, as shown in the minute following. Plans of the cottages are also here given. See Figs. 97, 98, 99, 100, and 101.

Cost.	£	s.	d.
Bricks and timber-work	55	0	0
Spouting	1	5	0
Kitchen range, &c. . .	2	15	0
Cement floor	4	0	0
Slating	7	5	0
Privy and Ash-pit . .	4	0	0
Stone for foundation, &c.	1	0	0
	£75	5	0

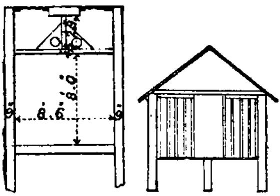


Fig. 101.

Bricks were supplied to the contractor at 20s. per 1,000 by the landowner.

Portable Wooden Cottages.—An extensive trade is now carried on in the manufacture of portable wooden buildings. They are all made in sections to screw together and can be put up in a very few hours, and taken down again, if required to be removed, by any carpenter, or even a handy labourer.

The sides of these houses are made of rough weather-boarding outside, and lined inside with varnished match-boarding. The floor is boarded, and the roof boarded and covered with patent prepared roofing felt. The windows are glazed with sheet glass, and the doors fitted with locks. The floors should be raised a little above the ground, and may rest either upon bricks, blocks of wood, concrete, or stone, whichever may be most convenient in the locality.

Improved Iron Cottages.—Galvanized iron houses, as now constructed by A. & J. Main & Co., Glasgow and London, and by Mr. Humphries, Albert Gate, S.W., are as healthy, comfortable, and convenient as ordinary structures. Special attention is devoted to ventilation and to sanitary and domestic arrangements, as well as to the neat and effective finish of the different apartments and fittings. The windows are made to open and close at pleasure, as in other houses; and all the apartments are floored, lined, and ceiled with wood, and finished with wood cornices, more or less ornamental according to the character of the house. Stores and presses are provided for domestic wants suitable to

Fig. 102.

the size of the house, and sanitary accommodation is always carefully considered.

Fig. 102 shows the elevation of a very convenient cottage of this description, by Mr. Humphries. The

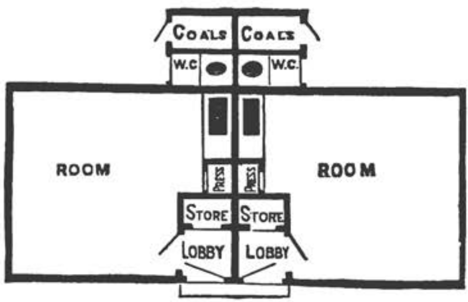


Fig. 103.

elevation, however, as well as the plan, may be varied in a great degree, without adding materially to the cost.

Plan 103 is a simple and inexpensive arrangement, by Main & Co., suitable for small cottages and coolie-huts, singly, or in a range of two or more together, but there are many other plans.

The framing is of wood, with the roof and walls of corrugated galvanized iron, floored, lined, and ceiled throughout with timber. The roof may be curved or ridge-shaped, the expense being nearly alike.

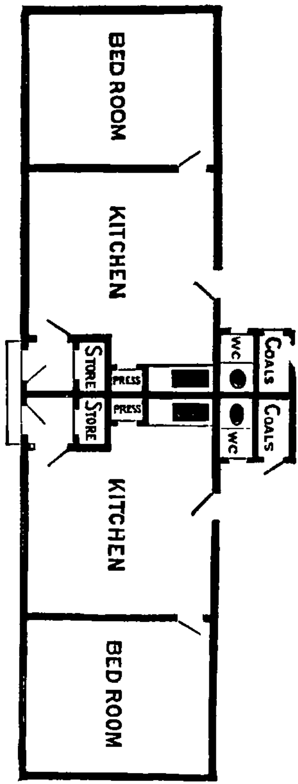


Fig. 104.

Referring to the "ground plan," it will be seen that lobby, store, presses, coal-house, and other necessary accommodation are provided for each house. Each apartment is finished with neat cornices, and ventilator to open or close at pleasure.

The following are an indication of the prices:—

Houses of single apartment, 14 ft. long by 12 ft. wide, door, windows, &c., with out-houses, as per ground plan No. 103, in sets of two or more, £47 10s. each.

Houses of two apartments, 24 ft. long by 12 ft. wide, with outhouses, as per ground plan No. 104, in sets of two or more, £70 each; houses of three apartments,

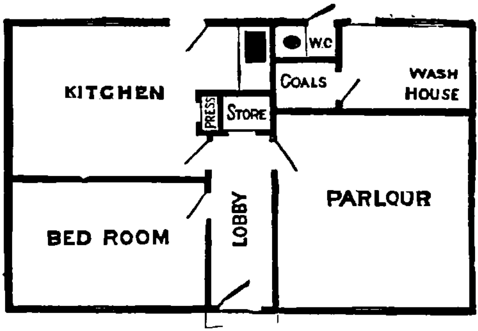


Fig. 105.

30 ft. long by 18 ft. wide, as per ground plan No. 105, £112 10s. each.

These iron houses, being very portable and easily erected, are well adapted for settlers in new districts.

APPENDIX.

SPECIFICATION FOR SIX COTTAGES AT , ON THE ESTATE OF , 1880.

Conditions.

1. *This contract embraces* the whole workmanship, labour, materials, haulage, cartage, &c., required in the construction of cottages, at , including drains, roads, outbuildings, &c., complete.

2. *All the materials*, of whatever description, must be of the very best quality, sound and free from all defects; and the workmanship must be of the best description throughout.

3. *The contractor to have* a competent foreman constantly on the work; and no part of the work shall be sublet, unless to parties previously approved of in writing by .

4. *The whole of the work* to be carried on and completed to the entire satisfaction of (and any inspector who may be deputed to look after the same), and any work which fails to obtain his approval will not be paid for.

5. *The stone used in the buildings* must be from an approved quarry, and the brickwork must be of sound, well-shapen, hard-burned bricks of the kinds specified for the several parts of the work.

6. *In case of any discrepancy* between the dimensions as

taken of scale and the written figures on the drawings, the latter are in all cases to be taken as correct.

7. *The contractor must send in* along with his tender the detailed schedule of prices from which it has been calculated, and any additions or deductions ordered by the inspector during the progress of the works must be done by the contractor at the aforesaid schedule rates.

8. *Any fences or gates* which may be damaged during the progress of the works must be at once repaired by the contractor at his own expense.

9. *All surplus materials* and rubbish must be removed at the completion of the contract, the roads left in an efficient state of repair, and the whole ground properly levelled and left in a clean and orderly way.

10. *Offerers must state* in their tender the time in which they undertake to complete the contract, and it is hereby expressly understood, in the event of the contractor failing to finish his contract by the time stated in the tender, he shall be subject to a discount of ten pounds sterling (£10) from the amount of his contract for every week's delay.

11. *Payments will be made* to the contractor monthly as the work proceeds to the amount of 90 per cent., in the opinion of the inspector of works, of the work done to his satisfaction. The balance will be paid when the whole has been satisfactorily completed; but monthly payments shall not invalidate the understanding that no money is to be considered legally due to the contractor till the whole work has been properly finished.

Specification of Works.*

Drains.—The full blue lines on general plan show the proposed drains, which shall be laid at least two feet clear under the surface of the ground. There will be a 9-in. diam. glazed socket-pipe along the back of each house or

* For erection of stone-built cottages, illustrated in Figs. 92, 93, 94, 95, and 96 pages 138 to 141 of this book.

row of houses, and connected by 4-in. glazed junctions opposite each of the end houses and every alternate house to 18-in. fireclay sinks placed in and of the same curved mould at the top as the surface channel, and fitted with grates, gullies, &c., complete. There will be a 6-in. glazed socket-pipe along the front of each row, which must be connected with the down-corners of spouting by 4-in. junctions. From the point of junction of the 9-in. and 6-in. pipes there will be a 12-in. pipe laid to carry the whole drainage into the culvert below the quarry. All the necessary eyes and junctions to be provided, and all joints to be carefully luted with well-tempered clay.

Channelling.—A firebrick channel to be laid along the entire length of the back and end walls of cottages, of the width of seven ordinary bricks set on edge, and at a distance of 3 ft. from the walls, a communication by ordinary small grooved channel bricks (glazed) being made with the down-corners of spouting.

Filling and Excavation.—All the walls in the whole buildings should be founded at the depths and to the widths shown on drawings, being in no case less than 18 ins. below the natural surface of the ground, and the excavated material deposited where required. The whole area occupied by the back-yards and lanes the full length of main streets shall be excavated or filled up, as the case may be, to a level of 9 ins. below the level of adjoining streets, and over the surface thus formed shall be spread a layer of slag or broken stones 7 ins. thick and covered on top with 2 ins. of dry coke ashes. The whole area inside houses shall also be excavated or filled to the requisite levels, the finished floors being in no case less than 6 ins. higher than the adjoining ground, and all the timber floors having a clear space of 9 ins. between the surface of ground and the bottom of sleeper joists. The houses shall be stepped down in accordance with the fall of the street at every alternate gable or party wall, the finished floors of two houses being always formed on the same level, and the gardens and back-yards shall be stepped with the houses and formed at a level of 6 ins. below the floors at the highest side of the ground.

Mason and Bricklayers' Work.

Mortar.—The whole of the mortar used to be mixed in the proportion of one part lime to two and a half parts sand. The lime to be obtained from lime-works and the sand to be clean, sharp, and coarse-grained.

Walls.—All the walls shall be built of good hard stone from an approved quarry. The face stones shall be all of an uniform colour, and all the quoins and ashlar stones shall be of white freestone and uniform in colour. The whole of the walls will be built close up to the sarking of roofs, and will be built crossband throughout, having beaders extending two-thirds the thickness of the walls in every foot of height, and from 3 ft. to 3 ft. 6 ins. apart. The foundations shall be of large flat bedded stones not less than 6 ins. in thickness, laid straight and close the first course, and built up straight, close, and plumb, to the dimensions figured on the drawings. All the walls will have 6-in. scarcements, the scarcements in the case of the rooms and passages with timber floors being built up 6 ins. broad to 8 ins. from the floor level for the sleepers to rest upon; and all the foundations of 6-in. division walls will be built up 14 in. thick to 8 ins. from the floor level. The external walls of houses will be 20 in. thick, the party walls 18 in. thick, and the thin division walls 6 in. thick, with division standards and horizontal warpings as afterwards specified. The walls of outbuildings will be 12 in. thick, and internal divisions 4½ in. thick. The division walls of back-yards will be 9 in. thick and 5 ft. above the finished level of ground. The external face of the whole walls will be entirely clean built of stones hammer-dressed to a regular thickness the full breadth of the beds, and built close, level, and plumb on the face, having no hanging faces, and entirely without pinnings. None of the outside face stones shall exceed 6½ in. in height, nor be less than 7 in. on the beds, and in every part of the buildings the stones must be laid on their broadest beds, which must coincide with the quarry bed. In no case shall any rubble stone throughout the buildings exceed in height the breadth of its bed, and no rubble stone will be built into the walls exceeding 7 in. in height. The 6-in. division walls will be built of rubble stone, the stones not exceeding 4 in. in thickness; and all the other walls in the whole buildings shall be built of stone, except the internal walls of coalhouses, which shall be of common bricks 4½ in. thick; and the whole of the masonry shall be well bedded in mortar, and the joints of external walls neatly drawn in and pointed as the work proceeds. The spaces round foundations of walls shall be filled in with broken stones to the level of the ground surface.

Cement Floors.—The kitchen floors, pantries of three-roomed houses, and all the outbuildings shall be laid with Wilkinson's Cement Flooring of not less than 2 in. in thickness of the cement mixture, which will be carried 6 in. up the walls by 1½ in. thick, without any break, so as to form a solid skirting. The cement to be laid on a good foundation of broken stones or bricks 3 in. in thickness, and broken to pass through a ring 1½ in. diameter, the space below having been previously filled in with dry materials well rammed and levelled before receiving the broken stones or bricks.

Fireplaces, Mantels, and Hearths.—The kitchen vents shall be built 14 in. by 12 in., and all the other vents 12 in. square, and the whole will be well plastered with strongly haired lime as the work proceeds. The kitchen fireplaces to have polished stone jambs 18 in. by 5½ in., and lintels 8 in. square, with a 1-in. chamfer off the inside angles all round, surmounted by a polished stone shelf 9 in. broad by 4 in. thick, having a bed moulding, and fitted with a substantial cast-iron range 62 in. by 48 in., complete with oven and 8-gallon pot. The front lower rooms in four-roomed houses to have polished jambs and lintels 3 ft. 2 in. square inside, and fitted with a suitable cast-iron grate; the jambs 16 by 5 in., and lintels 7 in. square. The whole jambs will be polished the full breadth and thickness specified, and each jamb in the front rooms will have three holes 1½ in. square by 2 in. deep, for fixing jamb mouldings. All the fireplaces in upper rooms shall be fitted with cast-iron mantels and grates 30 in. wide. And the whole of the grates, &c., shall be subject to the approval of the Company's engineer.

The briddlings for receiving the hearths of lower front rooms will be arched with thin stones, the arches 7 in. thick, and well grouted. The outside hearths of all the rooms downstairs will be 3 in. thick, of polished Arbroath stone 4 ft. 3 in. long by 1 ft. 10 in. broad in front of jambs. The upper rooms will have outside hearthstones of polished Arbroath stone 3 ft 6 in. by 1 ft. 8 in. by 3 ft.; and the whole fireplaces will have polished Arbroath inside hearthstones 2½ in. thick, neatly fitted in making up the whole space within the jambs.

Quoins, Heads, Sills, Rybates, &c.—The corners of houses, &c., will have white freestone quoins 1 ft. 8 in. long by 7 ft. thick, having a 7-in. droved head and face, back-filleted ⅝ in., and the tail neatly broached, having three stripes to the inch. The front doors will have polished jambs and lintels of white freestone, the jambs in one stone each 20 in. broad by 9 in. thick, and lintels 9 in. square. The front door-steps will be polished; the inside step 9 in. by 6½ in., and outside steps 4 ft. 6 in. by 1 ft. 10 in. by 6½ in. All the doors will have one outside step, and more if required. The front windows will have droved white freestone rybates, sills, and lintels; the outband rybates 1 ft. 8 in. long by 6½ in. thick, having a 5½-in. droved breast, and 7-in. droved head, back-filleted ⅝ in, and the tail neatly broached, having three stripes in the inch. The inbands will be 1 ft. 4 in. long by 7 in. thick, having a 5½-in. droved breast, and 7-in. droved head. The window sills will be 13 in. broad by 8¾ in. thick, having a ¾-in. washing, and ⅛-in. weather-guard, and neatly droved. The lintels will be 8 in. square, wrought high on the upper bed, to prevent water penetrating the walls, and neatly droved, having a 5½-in. droved breast, and wrought to correspond with the rybates. The lintels, door-steps, and window-sills in back of houses and in outbuildings will be of the same dimensions as those specified for the front of the houses, and the door and window rybates will be of large square-dressed stones.

The skew-blocks of gables will be moulded and droved, 2 ft. 8 in. long by 17 in. deep by 14 in. broad. The skews will be 14 in. broad by 4½ in. thick on the average, having a check at every 20 in., and neatly droved.

Chimney-Heads.—The chimney-head corners will be of single and double headers, making up the thickness of the haunch. The single headers will be 2 ft. long by 7 in. thick on the heads, and the double headers 20 in. by 12 in., having a 2-in. droved margin on the angles, and the tails neatly broached, having three stripes to the inch. The chimney-heads will have a droved moulded cope 9 in. thick, in three stones, having the vents cut off the solid, and batted together with iron bats run in with lead. And the chimneys will have water barges droved and splayed, 5 in. thick by 12 in. broad.

Ventilating Grates.—A cast-iron ventilating grate to be built in front wall of each house below the timber floor.

Carpenters' and Joiners' Work.

Safe Lintels.—The safe lintels of all the doors and windows shall be 4 in. thick by 12 in. broad, having filling-in lintels 3 in. thick making up the full breadth. The safe lintels of outbuildings 3 in. thick.

Ground Floors.—The sleeper joists of front lower rooms and lobbies will be 6½ in. by 2½ in., set on wall-plates 7 in. by 1¼ in., and placed 18 in. centres apart, and laid over with $1\frac{1}{8}$-in. flooring in 6-in. breadths, feathered and grooved on the edges, closely jointed and firmly nailed to the joists, and planed over after they are laid.

Bedroom Floors.—The bedroom floor joists will be 11 in. by $2\frac{1}{2}$ in., set on wall-plates 7 in. by $1\frac{1}{4}$ in., and placed 17 in. centres apart. The joists will be briddled for receiving the hearths and stairs, and the long briddled joists will be 3 in. thick, having two tenons, the upper one half through, and the under one through and wedged. The whole of the joists shall have 12 in. of wall-rest at each end. The whole upper floors will be laid over with white drain-flooring $1\frac{1}{8}$ in. thick, in 6-in. breadths, feathered and grooved on the edges, closely jointed, and firmly nailed to the joists, and planed over after being laid.

Ceiling Joists, Roofing, &c.—The whole of the ceiling joists will be 7 in. by $2\frac{1}{2}$ in.; roof spars $6\frac{1}{2}$ in. by $2\frac{1}{2}$ in; baulks, $6\frac{1}{2}$ in. by $2\frac{1}{2}$ in.; uprights of roof, 5 in. by 2 in.; valley spars, 9 in. by $2\frac{3}{4}$ in.; ridge-plates, 9 in. by 2 in. The ceiling joists and baulks will be half-checked on the ends, and dovetailed $\frac{3}{8}$ in. into the roof spars, and the uprights will be half-checked on the ends, and nailed to the spars and ceiling joists as shown in the section. Each checking will have three 40 lbs. per thousand nails through it. The ceiling joists or roof spars will be set on wall-plates 7 in. by $1\frac{1}{4}$ in., and placed 18 in. centre to centre apart. And the whole roofing will be covered over with white drain-sarking $\frac{3}{4}$ in. thick, in 6-in. breadths, half-checked on the edges, $\frac{3}{8}$ in. on the face, and will have two 15 lbs. per thousand nails through at each bearing. The gutter boarding will be $1\frac{1}{4}$ in. thick, supported on bearers 3 in. by 2 in., placed 18 in. centres apart. And the whole roofs will have ridge battens and filleting complete.

Door and Division Standards.—The front door standards will be 6 in. by $2\frac{1}{2}$ in., and standards of back exterior doors $5\frac{1}{2}$ in. by $2\frac{1}{4}$ in., firmly fixed with four strong iron split bats in each side, and run in with lead. The division door standards of thin walls on ground floor will be $7\frac{3}{4}$ in. by

2½ in., and the said walls will have rough division standards 6 in. by 1¾ in. set on a sole-plate 6 in. by 1⅛ in., and fixed to a top runner 5½ in. by 1¼ in., the standards placed on an average 2 ft. 4 in. centres apart, and warpings 6 in. by 1⅛ in. built in at every 2 ft. 3 in. in height. The division door-frames on bedroom floor will be 5½ in. by 2¼ in., and the lath division standards 3¾ in. by 2¼ in., placed 16 in. centres apart, and having a runner at top and bottom 3¾ in. by 2½ in.

Lathing.—The whole of the ceilings and division walls on both sides will be lathed over with the best Baltic split laths $\frac{3}{16}$ in. thick.

Angle Beads.—All external angles in the whole buildings will be finished with a 1⅛ in. diameter angle-bead.

Windows.—The whole window sash framing will be 2⅝ in. broad by 2¼ in. thick finished, the sash sole 3¾ in. broad; counterchecks, 1¾ in. thick; and ¾ in. thick Gothic mounted astragal. The pulley styles will be 1⅛ in. thick and inside facing 1 in. thick; case sole 4 in. thick; batten rod 1¾ in. broad, having ⅝ in. thick outside facing batten and parting rods. The upper sashes of kitchen and staircase windows will be hung, and all the other windows, including the kitchen windows of three-roomed houses, will be double hung with best patent axle brass-faced wheel pulleys, sash-line, and cast-iron weights complete. And the whole sashes of windows, and fanlights above front and back doors, shall be glazed with the best crown glass, entirely free of specks, waves, or blemishes of any description. The sashes will receive one coat of oil paint before being glazed and two coats afterwards. The cases will receive two coats of oil paint before being fixed, and two coats afterward.

Window Shutters and Linings.—The windows in front rooms down-stairs will have shutters bound in two panels in height, having double rail in centre showing cut; the styles and rails 1⅝ in. thick by 3½ in. broad, having sunk ogee moulding stuck on framing to correspond with the doors; the panels $\frac{5}{8}$ in. thick; and bound closers framed to correspond with the shutters but not moulded, having panels $\frac{7}{16}$ in. thick; and the whole will have bound soffits, breasts, and elbows $1\frac{1}{2}$ in. thick, framed and moulded to correspond with the shutters, having panels $\frac{5}{8}$ in. thick. And all the other windows in the houses will have shutters bound in two panels in height $1\frac{5}{8}$ in. thick, the styles and rails $3\frac{1}{2}$ in. broad, having a double rail in centre showing cut, and sunk mouldings stuck on the framing, and panels $\frac{5}{8}$ in. thick; with bound closers framed to correspond with the shutters but not moulded, having panels $\frac{7}{16}$ in. thick; bound soffits $1\frac{1}{3}$ in. thick, with panels $\frac{5}{8}$ in. thick, framed and moulded to correspond with the shutters; and plain breasts and elbows $\frac{3}{4}$ in. thick in regular breadths not exceeding 5 in., feathered, grooved, and beaded on the joints, and firmly fixed to three grounds in heights $2\frac{1}{4}$ in. by $1\frac{1}{8}$ in. The front room windows down-stairs will be finished with single facia architraves $5\frac{1}{2}$ in. broad; and the back windows down-stairs, and all the windows up-stairs with plain facings $5\frac{1}{2}$ in. broad by $\frac{11}{16}$ in. think, moulded on both edges. The architraves will have plates $\frac{11}{16}$ in. thick and all the architraves of windows and doors will be set on blocks ragglet $\frac{1}{2}$ in. into the floor, and the bases must stand the breadths specified above the floor when finished.

Doors and Door Linings.—The front door of houses will be framed and lined. The styles 5 in. by $2\frac{3}{8}$ in., having 4 rails in height 7 in. broad by $1\frac{1}{4}$ in. thick, moulded on the framing inside, and lined outside with lining in 5-in. breadths by $1\frac{1}{8}$ in. thick, feathered and grooved on the edges, closely jointed, and beaded on the joints. The exterior back doors of houses will be framed and lined; the styles 5 in. by $2\frac{1}{4}$ in., having 4 rails in height 6 in. by $1\frac{3}{16}$ in. chamfered and mitred inside of framing, and lined outside with lining in 5-in. breadths by $1\frac{1}{16}$ in. thick, fəathered and grooved on the edges, closely jointed and bəaded on the joints. The interior doors down-stairs will be bound in four panels, the framing 1⅞ in. thick, styles and top-rail 4½ in broad, and sill and belt-rails 9 in. broad, having panels ¾ in. thick when finished, and sunk moulding stuck on the framing. The closet door under stairs will be 1½ in. thick, framed and moulded to correspond with the other interior doors. The whole doors up-stairs will be bound in 4 panels having ogee moulding stuck on the framing; the framing 1¾ in. thick, styles 4½ in. broad, sills and belt-rails 9 in. broad, and panels ¾ in. thick. The coal-house and privy doors will be ⅞ in. thick, feathered and grooved on the edges, closely jointed and beaded on the joints, having three bars on back 6½ in. by 1⅛ in. thick. The privy seats and fronts will be 1⅛ in. thick, supported on bearers 2½ in. by 2 in. All the doors down-stairs will be finished with single facia architraves 5 in. broad, having plates $\frac{11}{16}$ in. thick; and all the doors upstairs will be finished with plain facings 3½ in. broad by $\frac{11}{16}$ in. thick, moulded on both edges.

Skirting.—The lobbies and front rooms down-stairs will have a base-plate 6 in. broad by 1 in. thick, with moulding on top 2¼ in. by 1¼ in., and will have a ground at back at every 20 in. centres apart. The staircases will have a skirting, and all the rooms up-stairs will have a base-plate 5½ in., and the closets and stair-landings on upper floor 5 in. broad. The whole ⅞ in. thick, ragglet ½ in. into the floor, and will have a moulding on top 2⅛ in. by 1⅛. in.

Mantelpieces.—The front rooms down-stairs will have mantelpieces having pilasters 8 in. broad, and frieze 8 in., having bed moulding and shelf on top 10 in. by 2 in. moulded on the edge. The pilasters and frieze framed of wood 1 in. thick.

Staircases.—The staircases will have 11 in. by 2½ in. outside stringboards, cut shewing an open end and having the breasts mitred into it. The inside stringboards will be 11 in. by 1½ in. and have the breasts and treads ragglet ½ in. into it. The treads will be 1½ in. thick, and the breasts or risers 1⅛ in. The treads will have a rounded bottle and fillet in front and returned on the ends. The stairs will have a strong wooden railing, with $2\frac{1}{2}$ in. by $1\frac{3}{4}$ in. wainscot moulded hand rail, which will receive three coats of varnish after all the other works throughout the houses are finished and the houses cleared of rubbish.

Door Stops.—The outside door stops of houses will be $\frac{7}{8}$ in. thick, and all the other door stops throughout the whole buildings will be $\frac{5}{8}$ in. thick finished.

Shelving.—There will be 10 lineal yds. of utensil plate 5 in. by $\frac{7}{8}$ in. fitted up on dooks in each kitchen or such places as will be pointed out. And there will be 10 lineal yds. of shelving 15 in. by $1\frac{1}{4}$ in. fitted up in pantry or store closet of each house, on strong open brackets made of wood $2\frac{1}{2}$ in. by $1\frac{1}{8}$ in. The closets under stairs will also be fitted with two tiers of deal shelving 12 in. by 1 in. on similar brackets.

Ventilators.—In the case of the rooms without fireplaces a framing of wood 3 in. by $1\frac{1}{4}$ in. to be fitted in ceiling, leaving a $\frac{3}{4}$ in. batten door fitting into a rebate and opening on two hinges, and provided with fittings and cords, so that it may be opened as a ventilator. A circular louvre ventilator will be placed in the outside gables to communicate with the ventilators in ceiling. The framing of louvre ventilator to be $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in., with sufficient louvre boards, all properly dressed and fitted and built round as shown.

Timber.—The whole of the sleeper and bedroom floor joists, wall-plates, flooring down-stairs, lobby-flooring, staircases, outside doors, and door frames, window sashes and cases, and safe lintels will be of the best crown memel. And all the inside doors, window shutters and closers, breasts, soffits, and elbows, architraves, facings, door stops, skirting, and mantelpieces will be of best American St. John's yellow pine. And the roof spars, ceiling joints, baulks, uprights of roof framing, valley, ridge-plates, gutter boarding, bedroom flooring, sarking, inside door and division standards, rough standards and warpings, shelving and brackets, privy seats and bearers, will be of white grain of the best quality. The whole timber to be thoroughly seasoned and free fro sapwood, shakes, large or loose knots, &c.

Ironmongery.

The front exterior doors of houses will be hung with three 8-in. double joint edge hinges, and all the other bound doors, including the kitchen and coal-house doors, will be hung each with two 7-in. D. J. edge hinges, and all the plain deal doors with two 20-in. T-hinges. And all the house doors will be fitted with approved brass mountings. All the window shutters will be hung each shutter with four $3\frac{1}{2}$-in. D. J. edge hinges, and each closer with four 2-in. D. J. flat hinges. The front doors of houses will each have 9-in. iron rimmed lock value 9s. 6d., and the back kitchen doors will have each a good strong 7 in. iron-rimmed lock value 8s. All the interior doors will have strong 6-in. mortice locks.

The privy will have a malleable-iron thumb-lifting latch, and 6-in. bolt inside. The coal-houses a strong thumb-latch and 8-in. mortice lock.

The shutters will each have brass knob $1\frac{3}{8}$ in. diameter. And each window throughout the houses will have a malleable-iron swing shutter-fastener $2\frac{1}{4}$ in. by $\frac{5}{16}$ in. thick, riveted to a plate and fixed on with screws.

All the windows will have strong brass spring fasteners, and the front rooms downstairs will have two strong brass sash-lifters to each window.

Painting.—All the woodwork usually painted throughout the buildings shall have three coats of good oil and lead paint of approved colours.

Plumber Work.—The valleys and gutters will be of lead, weighing 6 lbs. per square foot, and not less than 12 in. broad.

The ridges will be 12 in. broad, of zinc weighing 32 oz. per square foot.

The whole eaves of buildings will have 4½-in. zinc water-runs, made with a bead in front, of zinc weighing 32 ozs. per square foot, and will be laid in galvanized iron straps $\frac{3}{16}$ in. thick, 2 ft. from centre to centre, having 7 in. hold of the sarking, and fixed with three nails to each strap.

There will be a cast-iron fall-pipe 3 in. diameter, with proper heads and shoes complete, between every two houses at both front and back, and discharging into the drains and sinks as previously specified.

Slater Work.—The whole roofs will be slated over with the best Bangor blue slates, 13 in. by 7 in., double nailed with nails prepared in oil, weighing 9 lbs. per thousand, and having 2½ in. overlap. And all the gable skews, &c. will be carefully pointed with cement.

Plaster Work.—The whole of the ceilings and walls will be finished in the best three-coat plaster; the first coat strongly haired, also the second coat, which will be well straighted and floated, and the finishing coat strongly gaged with stucco.

The whole of the window cases will be bedded and set in well-haired lime, and will be ripped back from the outside and pointed with mastic prepared in oil.

Outbuildings.—The ash-pit walls will be built 4 ft. high above ground on the inside, and 6 ft. high on side next lanes, and the ash-pit and back-yard division walls will be surmounted by a semicircular hammer-dressed stone cope 6 in. thick. There will be openings 2 ft. square, with heads and sills of stone, for putting in coals and clearing out ashes. The openings will have frames 2½ in. by 2½ in., and ¾-in. batten doors with 6-in. bolts. The walls of privy to receive one coat of plaster and set, and the coal-houses to be twice lime whitewashed. The floors of outbuildings will be of cement, as previously specified. The roofs will have 6½ in. by 2½ in. ribs, 3½ in. by 2½ in. spars set 16 in. apart, on wall-plates 7 in. by 1½ in., and covered with ¾-in. sarking, and slated in the same manner as the houses, and capped with a fire-clay coping 3 in. thick.

If any discrepancy occurs between the dimensions on plans, as taken by scale, and the figures written thereon, the latter are in all cases to be adhered to.

It is expressly understood that whatever omission may have occurred in this specification or on the accompanying drawings, such articles must nevertheless be completed like corresponding portions of the works, and the contract embraces every item of expense necessary to render the whole buildings and surroundings complete and fit for occupation.

TENDER FOR COTTAGES AT .

To ———

SIR,

I hereby offer to perform the whole work required in the construction of cottages at , and to provide all materials and labour necessary to complete the same in strict accordance with the relative drawings and specifications and to the entire satisfaction of your inspector of works, for the lump sum of , which sum embraces all the outbuildings, drains, and every other item necessary to complete the whole work, whether the same be specified or not.

This tender is based upon the accompanying schedule of prices, at which prices I agree that all additions or deductions shall be calculated.

And I further undertake to finish the whole work and hand over the whole of the cottages and outbuildings ready for occupation on or before the day of , under penalty of a deduction of £10 sterling from the amount of my tender for every week's delay beyond the aforesaid time for completion.

(*Name in full.*)

(*Address.*)

(*Date.*)

MEASUREMENT OF ONE COTTAGE.*

	£	s.	d.
Cutting tracks of 18-in. walls; 19 cub. yds. at 8d.	0	12	6
7 yds. of 6-in. pipe for drain at 1s. 6d.	0	10	6
39 cub. yds. of ballast at 1s.	1	19	0
18-in. walls; 166 sup. yds. at 3s. 2d.	26	5	4
12-in. walls; 58 sup. yds. at 2s. 9d.	7	19	6
9-in. brick walls; 20 sup. yds. at 3s. 9d.	3	15	0
4½-in. brick partitions; 65 sup. yds. at 2s.	6	10	0
Door and window-sills and lintels; 67 lin. ft at 1s.	3	7	0
Door and window-jambs; 76 lin. ft. at 5d.	1	11	8
Hewn corners; 6 lin. ft. at 1s.	0	6	0
2 gable corbels at 3s.	0	6	0
Water tabling; 15 lin. ft. at 6d.	0	7	6
4 flues at 10s.	2	0	0
4 flues at 5s.	1	0	0
Jambs and lintels; 25 ft. at 1s. 2d.	1	9	2
12 sup. ft., door threshold and hearths, at 6d.	0	6	0
Cement floors; 66 sup. yds. at 2s. 2d.	7	3	0
6 in. × 1½ in. skirting; 148 lin. ft. at 3d.	1	17	0
1 gully and trap at 5s.	0	5	0
Roofing 7 squares of 100 ft. at 16s.	5	12	0
Roofs of pantry and coal-house; 1¾ squares at 16s.	1	8	0
Joisting and flooring; 57 sup. yds. at 3s. 1d.	8	15	11
Safe lintels; 11 in. × 3 in., 58 lin. ft. at 4d.	0	19	4
Ceiling; 4½ squares of 100 ft. at 12s.	2	14	0
Angle beads; 65 lin. ft. at 1½d.	0	8	1½
Stoothing; 30 sup. yds. at 1s.	1	10	0
Front door; 21 sup. ft. at 10d.	0	17	6
Back door; 21 sup. ft. at 6	0	10	6
Closet and pantry doors; 40 ft. at 5d.	0	16	8
2 pairs door frames, 4½ in. × 3 in., at 5s. each	0	10	0
Coal-house doors; 18 sup. ft. at 3½d.	0	5	3
1 pair door standards at 4s. 6d. per pair	0	4	6
5 pairs ,, 6 in. × 2 in., at 5s.	1	5	0
Carried forward	86	18	11½

* Stone-built cottage, as per drawings, pp. 138 to 141; and specification, pp. 148 to 161.

	£	s.	d.
Brought forward	86	18	11½
1 staircase at 50s.	2	10	0
Windows; 95 sup. ft. at 10d.	3	19	2
1½-in. panel doors; 33 sup. ft. at 8d.	1	2	0
1¼-in. ,, 57 sup. ft. at 6d.	1	8	6
5-in. × ⅞ in. skirting; 284 lin. ft. at 2d.	2	9	0
Facings, 3½ in. × 1⅙ in.; 320 lin. ft. at 1½d.	2	0	0
1 mantelshelf, at 3s.	0	3	0
Pantry shelving; 32 sup. ft. at 3½d.	0	9	4
Painting; 132 sup. yds. at 5d.	2	15	0
Glazing; 75 sup. ft. at 5d.	1	11	3
Lath and plaster; 109 sup. yds. at 1s.	5	9	0
1 coat plaster on walls; 265 yds. at 7d.	7	14	7
Allow 12 in. for eaves, slater work; 102 yds. at 2s. 2d.	11	1	0
Ridging; 20 lin. ft. at 8d.	0	13	4
Eave spouting; 17 lin. yds. at 2s. 4d.	1	19	8
3-in. downfall pipes; 7½ yds. at 1s. 6d.	0	11	3
Lead flashing; 11 sup. ft. at 1s. 3d.	0	13	9
Drains	3	4	6½
Total for one house	£136	13	4

INDEX.

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SCOTT'S FARM ENGINEERING TEXT-BOOKS

V.

BARN IMPLEMENTS AND MACHINES

A

PRACTICAL TREATISE

ON

THE APPLICATION OF POWER TO THE OPERATIONS OF AGRICULTURE AND ON VARIOUS MACHINES USED IN THE THRESHING-BARN, IN THE STOCK-YARD, AND IN THE DAIRY, ETC. ETC.

PREFACE.

THIS volume will, we hope, give the agricultural student and the young farmer some idea of the giant strides which have latterly been made in agricultural mechanics, and which are still going on. The progress in this respect has been of a three-fold character. New machines have been invented and old ones greatly improved; new motive powers have been utilised to work them; and new methods of transmitting power and of arranging barn machinery have of necessity followed.

It has been deemed proper to devote a considerable section of the present book to an elucidation of the motor powers now in use, or likely to come into use, on the farm. The principle of the steam-engine has naturally been expounded at some length. Gas-engines, hot-air engines, turbines, and other water motors, have also been described as fully as space would permit. And in anticipation of the time, not very distant, we imagine, when the ploughman will be seen riding on his plough with one or more days' store of electric energy under the seat, and the implement he steers turning over the soil with a speed, ease, and economy that immeasurably distances even the best performances of the steam-plough, electricity as a motor power, has received some share of attention.

Fixed barn works are now a thing of the past. The ponderous fixtures found in many barns erected within the last quarter of a century are now judged unnecessary, both on account of their expense and because they absorb too much power for the amount of work they perform.

In working barn machinery, horses are superseded to a great extent by the steam-engine, or, where that is found too expensive, a hot-air engine, a gas-engine, or a water motor is now commonly employed. In such cases the method of transmitting power is usually through belting or by means of a driving-shaft, instead of toothed wheels. If horse-gear is used, none of the old expensive horse-wheels are erected, a portable description having taken their place.

Since the days of "Old Mortality," and the introduction of the winnowing-machine, when the use of that artificial aid to separating the chaff was regarded as a direct thwarting of the will of Providence, the farm-yard has been invaded by a host of inventions, some of them far more wonderful in their way than the "new-fangled" machine which created such consternation in the minds of the good people of Tillietudlem.

In the barn itself, the winnowing-machine has been fairly eclipsed by the modern threshing-machine; and under the same roof, without an exception almost, we meet with the still more recent machines, the chaff-cutter, the root-pulper, the cake-crusher, and corn-bruiser. In the rick-yard, we find machines for artificially drying hay and corn, for stacking hay and straw, and for trussing, baling, and compressing fodder of all kinds. In the dairy, again, there are machines which artificially separate the cream from the milk, and a great variety of others all tending to improved methods of dairying. And in the poultry-yard, amongst the marvels of the age, we may number the artificial mothers or incubators and the cramming-machine.

These are only a few of the more recent barn implements and machines.

CONTENTS.

LIST OF ILLUSTRATIONS.

BARN IMPLEMENTS AND MACHINES.

CHAPTER I.

MOTIVE POWERS.

THE sources of energy may be summarised as tides, food, fuel, wind, rain, and solar heat.

Tides are a practical source of energy, because of the existence of tide-mills; but it is a source which can only be rare in its use as compared with other motors. It is difficult in the case of docks to economise tidal energy by artificial dock basins, but there are places in the world where it would be possible, and even advantageous, to build a sea-wall across the mouth of a natural basin or estuary, and utilise the tidal energy, filling and emptying it by means of sluices and water-wheels. If this, however, can be done, but little more would be needed to keep out the water altogether, and make fertile land of the whole basin. It thus becomes an interesting economic question: "Which is most valuable, 40 acres of land, or the 100 horse-power which would be produced by 40 acres of water obtained in the way referred to?" In one case the answer would be the horse-power, in another the acres; but the question is hardly worth answering, considering the rarity of the cases where embankments for the utilisation of tidal energy are practicable Much information as to sea-power and tidal-mills will be found in Sir R. Cane's valuable work, the "Industrial Resources of Ireland."

Food is productive of *manual* and *horse-power;* just as *fuel* is the instrument which gives power to the *Steam-Engine*, the *Gas-Engine*, and the *Hot-air Engine*. Each of these will be found treated of in a different part of this work.

Wind-power has more or less fallen into disuse, but this decadence may not be permanent. The coal-pits are becoming exhausted, slowly though surely, and the price of coal tends upwards. Long before coal is exhausted, therefore, wind may be again brought into greater requisition both on land and at sea. Even now it is not utterly chimerical to think of wind superseding coal in some places for various purposes. But until new inventions are made it does not seem probable that wind can be economically used in any considerable class of cases, or to put energy into store for work of other kinds. In another volume of this series ("Irrigation and Water Supply") the value of wind-power for pumping water for the supply of the homestead, and for watering and irrigating fields and gardens, has been referred to; and illustrations and descriptions of the most effective wind-mills at present available for such purposes are also given.

Rain-power has been chiefly utilised on the farm in the shape of collected drainage-water to drive threshing and other machines; but the splendid suggestion of Sir W. Siemens that the power of Niagara might be utilised by transmitting it electrically to great distances, has given quite a fresh departure in respect of economy to rain-power. The difficulty of economising th electrical transmitting power to great distances may now be accounted as overcome, and it is impossible to foresee what may not be the effect in the future.

Sun-heat may also possibly be utilised with good effect as a motor-power—at least in tropical regions—long before our coal-fields are exhausted. M. Mouchot's solar engine is an example of what may be done in this direction. It is stated that an improvement of Mouchot's engine, devised by M. Pifre, has gone so far as to utilise 80 per cent. of the available heat of the sun's rays at Paris; and the latter has actually constructed an apparatus with which he pumped water to a height of 10 ft. at the rate of over 20 gallons a minute. As in Mouchot's solar engine, a reflector receives the light and concentrates it upon a boiler, in this case containing nearly 90 gallons of water, which, under a clear Paris sky, begins to boil in about 40 minutes, and in a few minutes longer has sufficient pressure to drive the engine working the pump. In the not distant future, then, tropical countries will be the place where motive power can be had for next to nothing.

CHAPTER II.

WATER-POWER.

Of all motive power the one obtained from a fall of water is the best suited and cheapest for the agriculturist, and if it can possibly be obtained, is well worth considerable trouble and first outlay.

Water-Wheels.—Hitherto, in the farm at least, the motive power of water has been chiefly applied to drive machinery by means of the old water-wheel, which is of three kinds—the *overshot*, the *breast*, and the *undershot* wheel.

The overshot wheel is the most powerful of these, as in this case the whole fall of the water being something greater than the diameter of the wheel, is employed in producing the power, which in some cases, where the machinery is of superior description, is as much as 75 per cent. of the actual fall of water.

The water is supplied to the wheel from a trough or shoot, the bottom surface of which should be about 0·4 of a foot from the crown of the wheel to allow of the water obtaining a little greater velocity than the outer edge of the wheel. On some wheels the water is admitted a little below the crown, in which case the wheel is made of a greater diameter than the depth of the fall. The width of the trough should be something less than the width of the wheel, to prevent waste, and allow for the escape of the air from out of the buckets.

The overshot is best adapted for small streams of considerable fall; and the breast-wheel for large streams with a small fall; while the undershot is chiefly used as a flood wheel, or for obtaining motive power from the ebb and flow of the tide.

These wheels, however, being both cumbersome and costly, are being rapidly superseded by the cheaper, more efficient, and more convenient Turbine and Water-Engine.

The Turbine.—The turbine is an improved machine for applying water-power, and is adapted for working all descriptions of machinery. It is equally suited for low and high falls, and possesses great advantages over the ordinary vertical wheel. In first cost it is almost invariably much cheaper; it is erected at less expense, a small bed of masonry only being required as a foundation, whilst it yields the highest obtainable percentage of power from a given quantity of water. The speed needed for driving machinery is also obtained direct from the wheel-shaft, without the heavy intermediate gearing required with the ordinary wheel, as the turbine makes, on falls of average height, from 200 to 500 revolutions in a minute.

Turbines have long been extensively employed on the continent, and more recently in the United States of America, and have been constructed in a great variety of forms, some of them being so designed as to attain a high efficiency, whilst others are altogether unsuited for use where economy in the consumption of water is desired. When properly constructed, however, the turbine cannot be excelled as a means of applying water-power, and it possesses many important advantages over the ordinary water-wheel.

Among the most obvious of these advantages the following may be enumerated:—

1st. It is usually much cheaper in cost, especially for high falls.

2nd. It is erected at less expense, a small bed of masonry only being required as a foundation.

3rd. It yields the highest obtainable power from a given quantity of water, and is equally efficient for high and low falls. On low falls it greatly exceeds the ordinary breast and undershot wheels in economising the water.

4. Its action is not impeded by back-water, consequently it may be placed at or below the level of the water in the tail-race. The entire fall is thus rendered available at all times, whilst the ordinary wheels (for low falls especially) in order to be out of back-water in floods, often require to be placed so high as, in dry weather, to cause an important part of the fall to be wasted in the tail-race.

5th. The number of revolutions it makes per minute is such that the speed required for driving machinery can usually be obtained direct, or with a single pair of small wheels in lieu of the heavy intermediate gearing needed with the ordinary water-wheel.

6th. From its small size it can be employed in many situations where the cumbrous vertical wheel is not available.

Amongst the turbines generally used on the continent, and which have been introduced to some extent in this country, those invented by Fourneyron (in which the water is admitted to the central part of the wheel and passes out of the circumference) and by

Jonval or Fontaine (where the flow is in a direction parallel with the axis), are the best in principle, and have attained the highest efficiency.

The Vortex Turbine or Water-Wheel.—The "Vortex" is an improved form of turbine, the invention of Professor James Thomson, and has been manufactured for many years by Williamson Brothers, who are now sole licensed makers. During this time it has been brought into most extensive use for a great variety of purposes in all parts of this country and abroad. It has been applied on falls ranging from 3 ft. to 400 ft. Its superiority as a means of applying water-power has been generally recognised by those who have had experience of its working.

The Vortex consists of a movable wheel with radiating vanes, which revolves upon a pivot, and is surrounded by an annular case, closed externally, but having towards its internal circumference four curved guide passages. The water is admitted by one or more pipes to this case, and issuing through the guide passages, acts against the vanes of the wheel, which is thus driven round at a velocity proportionate to the height of fall. The water having expended its force, passes out at the centre, and below the case.

The advantages of the Vortex wheel or inward flow turbine over other forms of turbine have been stated by the late Professor Rankine to be due to the following four circumstances :—

I.—Its discharging water near the centre of the wheel.

II.—The action of centrifugal force in regulating the pressure of the water within the wheel.

III.—The mode of varying the supply of water when required.

IV.—The action of centrifugal force in regulating the speed.

I.—The advantage of discharging the water near the centre of the wheel is of the following kind: In every form of turbine a whirling motion is given to the particles of water before they begin to drive the wheel, and the efficiency of the turbine depends on the completeness with which that whirling motion is taken away from those particles during the action on the wheel. By discharging the water from a part of the wheel whose motion is comparatively slow, the practical fulfilment of that condition is rendered more easy and certain.

II.—The action of centrifugal force in the regulation of the pressure within the wheel is of the following kind: It is favourable to economy of power that the effective pressure of the water immediately after entering the wheel should bear a certain definite proportion to the effective pressure in the supply-chamber not differing much in any case from one-half. The centrifugal force of the water which whirls along with the vortex wheel tends to preserve at its circumference the very pressure which is most favourable to economy of power; and the centrifugal force of the two discs of water contained between the wheel and the two shields or covers of the wheel-chamber prevents that pressure from making the water leak out between the wheel and the casing.

III.—The action of centrifugal speed is as follows: Should the load be suddenly diminished and the wheel begin to revolve too fast, the centrifugal force of the water whirling along with it increases and opposes the entrance of water from the supply chamber; on the other hand, should the load be suddenly increased and the wheel begin to revolve too slowly, the centrifugal force of the water whirling along with it diminishes and allows more water to enter from the supply-chamber; and thus sudden variations of the load are prevented from causing excessive fluctuations of speed —the whirling water acting as a governor. In outward-flow turbines, the centrifugal force of the water acts in a contrary way and tends to increase the fluctuation of speed. In parallel-flow turbines it has no sensible action of either kind.

IV.—The advantage of the mode of varying the supply of water to the vortex wheel by means of movable guide-blades turning about their inner ends, is of special importance, and consists in this, that how small soever the supply of water may be made the passages through which it flows are always of a smooth and continuous form, and free from enlargements and from sudden contractions or throttlings; which causes of waste of power can never be wholly avoided when the supply is regulated by sluices or slide valves.

The construction of the vortex and the mode in which the water is applied in it, will be readily understood by reference to Figs. 1 and 2.

The vortex represented in Fig. 1 is shown with the cover removed. Fig. 2 shows the case complete, as it is usually placed at the bottom of the fall. A is the revolving wheel keyed on the shaft C, B one of the guide-blades, D the bell-cranks and shafts connecting the guide-blades with the outside bell-cranks and coupling-rods E, F guide-blades gear, G bracket and screw for raising the pivot (the pivot cannot be seen in the sketch), H wheel-cover, and I supply-pipe by which the water enters the case.

In Fig. 3 the vortex is shown in position, arranged vertically, with part of the fall acting by suction. It

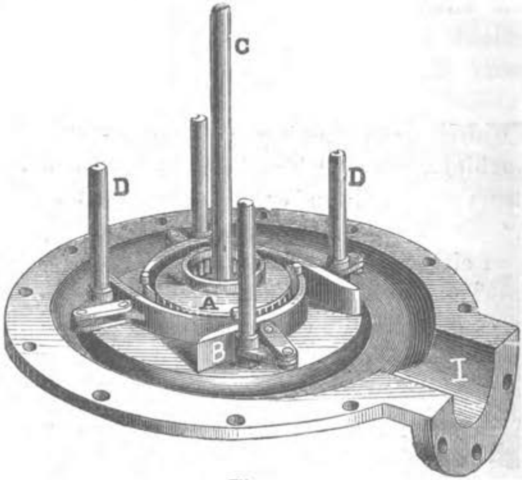


Fig. 1.

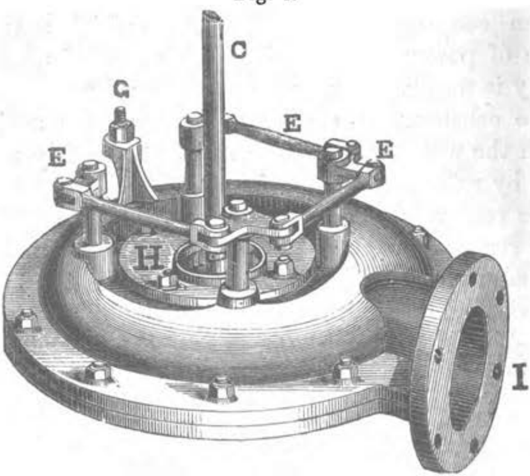


Fig. 2.

may be thus placed at any height not exceeding 30 ft.

above the tail water. The water after it leaves the vortex passes by two pipes into the tail-race, and by "suction" in these pipes the fall below the wheel is utilised. The vortex stands upon two beams placed

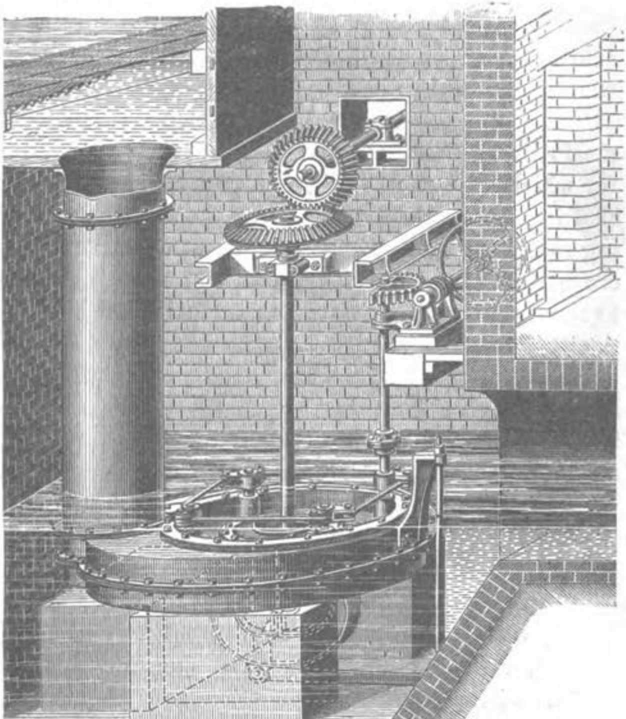


Fig. 3.

across the pit or well leading to the tail-race. The shaft is horizontal, and passes through stuffing-boxes in the bend of the suction-pipes. The power is taken from the pulley, which is shown upon the shaft.

In the engraving a portion of the pen-trough is represented as broken away, so that the cast-iron strainer plates, which are used to prevent the entrance of stones, sticks, &c., into the turbine, may be seen.

Messrs. Williamson Brothers have erected one of these vortex turbines at the Homescale Farm, Old Hutton, near Kendal, for W. E. Maude, Esq., who writes as follows :—

"The turbine-wheel you have made and erected for me is in constant use, and fully answers the purpose for which it was intended. I may also add that the shafting and all the agricultural implements, threshing machine, winnowing-machine, straw-cutter, cake-crusher, and turnip-pulper, which you have attached to the turbine-wheel, work satisfactorily all together. A circular saw is being attached.

"The wheel, which is 10 ins. in diameter, and driven by a 30 ft. column of water, confined in a 9-in. pipe, is, in the opinion of Mr. Knowles, who manages the farm, equal to the united force of eight farm horses. The threshing-machine alone required four good horses last year.

"Wherever a small stream of water or reservoir, coupled with 20 to 30 ft. fall, can be obtained, I think turbines may be applied with great advantage for agricultural purposes, being very simple and always ready, whereas steam-engines require an attendant possessing some mechanical knowledge, coal, and probably more repairs than the beautiful adaptation of water-power in question."

Fig. 4 represents a 5-horse power turbine with a fall of 16 feet, with adjustable blades. It is working a 4-horse power threshing-machine direct from the pulley on the turbine-spindle. The turbine-spindle is

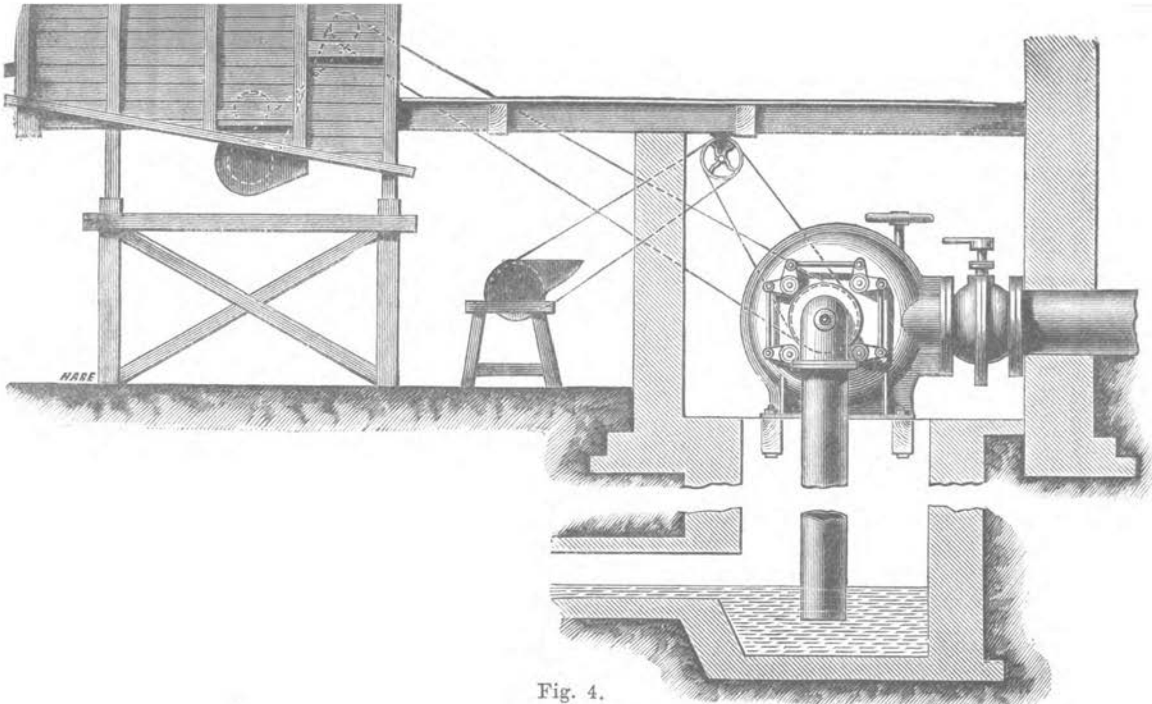


Fig. 4.

running at 300 revolutions, and the drum-spindle of the threshing-machine at 1,000 revolutions, per minute. There is no loss of power by intermediate gearing. The drum of the threshing-machine is 36 inches long, and the grain is once dressed after being threshed. The turbine supplies a surplus of water, and, without increasing it, elevators or corn creeps may safely be added; as, when the guide-blades are opened to their fullest extent, the turbine will yield 6½-horse power. In dry weather, when very little water can be obtained, by closing the guide-blades it is possible to use to advantage all that there is; and root pulper, chaff-cutters, &c., may at any time be worked off the barn-shaft without more water than is actually required to do the work being used.

If our engraving had illustrated a turbine with 150 feet fall, the turbine and pipes would have been very much reduced in size, as only about $\frac{1}{10}$ of the water would have been required to do the same work. Under any circumstances, the speed of the spindle of the turbine for ordinary farm purposes is such, that it may be connected direct by belt either to the line-shaft in the barn or to the drum-shaft on the threshing-machine.

Water-Engines.—Bailey's water-motor is one of the most economical types of water-engine ever invented, as every drop of water exerts force. Actual experience at high pressures demonstrates that it is possible to obtain 86 per cent. duty with these motors.

The water-pressure engines have no valves, cocks, springs, or other delicate machinery liable to derangement.

Bailey's water-motor, as shown in the engraving, is used in the stables of Sir H. Hussey Vivian, Bart., M.P., at Swansea; and also in Major Best's stables at

Llangollen, for chaff-cutting, oat-bruising, pumping water, and other purposes.

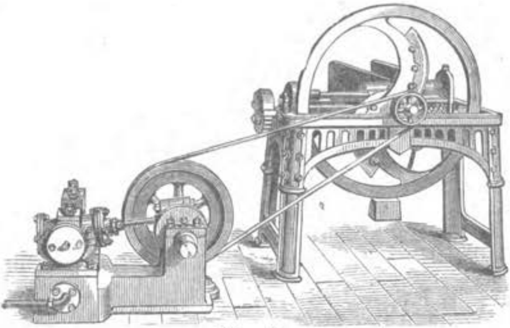


Fig. 5.

Prices for pressures from 20 lbs to 90 lbs. on the square inch.

Size.	Bore of Cylinder.	Revolutions per Minute.	Diameter of Pipes.		Feet.		98	131	164	196	† Air Vessels extra.		
					Lbs.		*45	60	75	90			
							Approximate Horse Power with the above pressures.						
No.				£	s.	d.					£	s.	d.
2	$1\frac{3}{4}$	220	1	10	0	0	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{2}{5}$	$\frac{1}{2}$		5	0
1A	$2\frac{1}{4}$	200	$1\frac{1}{2}$	12	10	0	$\frac{1}{2}$	$\frac{2}{3}$	$\frac{5}{6}$	1		6	6
3A	$3\frac{1}{8}$	160	$2\frac{1}{2}$	15	0	0	1	$1\frac{3}{8}$	$1\frac{3}{4}$	2		7	6
4	4	140	$2\frac{1}{2}$	25	0	0	$1\frac{3}{4}$	$2\frac{1}{4}$	3	$3\frac{1}{2}$		12	6
5	$4\frac{3}{4}$	120	3	35	0	0	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{4}$		17	6
6	$5\frac{1}{2}$	100	4	50	0	0	3	4	5	6	1	5	0
7	$6\frac{3}{8}$	90	$4\frac{1}{2}$	65	0	0	$4\frac{1}{2}$	6	$7\frac{1}{2}$	9	1	12	6
8	7	85	$4\frac{3}{4}$	80	0	0	$6\frac{1}{4}$	$8\frac{1}{2}$	$10\frac{1}{2}$	$12\frac{1}{2}$	2	0	0
9	$9\frac{7}{8}$	80	$5\frac{1}{4}$	95	0	0	8	$10\frac{1}{2}$	$13\frac{1}{2}$	16	2	7	6
10	$8\frac{5}{8}$	75	$5\frac{1}{4}$	120	0	0	$9\frac{3}{4}$	13	$16\frac{1}{4}$	$19\frac{1}{2}$	3	0	0
11	$9\frac{1}{2}$	70	6	140	0	0	12	$15\frac{3}{4}$	$19\frac{1}{2}$	$23\frac{1}{2}$	3	10	0
12	$10\frac{1}{4}$	65	6	180	0	0	$14\frac{1}{2}$	$19\frac{1}{4}$	24	29	4	10	0

These motors, if specially ordered, will do for either steam or water.

*** It will be obvious that at half 45 lbs. pressure, that half the power will be developed, in other words, the lower the pressure is, the larger will be the motor required.**

† An air vessel on the inlet prevents vibration and increases the power.

CHAPTER III.

THE STEAM-ENGINE.

The mechanical action of steam is usually accomplished by a piston moving in a cylinder. The cylinder is a tube in most cases of greater length than the proportion of its diameter.

The piston is a plug fitted accurately to the bore of the cylinder, not so tightly as to prevent its being easily slid from one end of the cylinder to the other, yet sufficiently so as to prevent the passage of steam between it and the side of the cylinder.

Attached to the piston on one side in its centre is a circular rod accurately turned from end to end, called the piston-rod.

Each end of the cylinder is closed by lids, through one of which the piston-rod passes; this is kept perfectly steam-tight by a packing of hemp soaked in oil and tallow.

A blast of steam being admitted on one side, the piston is forced onwards to the other end, and a similar blast being admitted on that side (and the means of escape being opened on the other), the piston is then pushed back to its former position; thus the primary power produced by steam-power is an alternate motion backwards and forwards in a straight line; but by an infinite number of well-known mechanical contrivances, this alternate motion may be made to produce any other kind of motion that may be desired; thus, we may make it keep a wheel in constant rotation, or move a weight continually in the same straight line, and in the same direction. The various details by which these objects are effected, and which constitute the working parts of the engine, we will now proceed to describe separately.

First, the means by which steam is admitted into and allowed to escape from the cylinder. This requires two apertures to be made at each end of the cylinder, one for the admission, and the other for the escape, of the steam; the first must have a communication with the boiler, and the latter with the vessel where the steam is condensed, as in condensing engines, or into the atmosphere, where it escapes, as in high-pressure engines.

These apertures, or steam-ports, must of necessity require to be alternately opened or shut, which is done by contrivances called puppet-valves—those which open a communication with the boiler being called steam-valves, and those which open the communication with the condenser are called exhaust-valves.

These valves are conical discs, fitting lightly into holes, from which they are lifted or drawn, and to which they return alternately: they are made of gun-metal, with their faces ground so as to fit with the greatest precision.

In lieu of these valves an arrangement is often made for effecting the same end by what are called slides. The two openings to the cylinder in this case being ground to a flat surface, upon these two plates or discs, also ground to a true surface, pass backwards and forwards, thus covering or uncovering by pairs the openings for the admission or escape of the steam.

The manner in which these valves act is thus: Supposing the cylinder to be placed in a vertical position (which it is not always), when the piston arrives at the top of the cylinder, two valves, the upper steam-valve and the lower exhaust-valve, are required to be opened, and at the same moment the two other valves, the lower steam-valve and upper exhaust-valve, must be closed. Now, as all these movements are simultaneous, it may be easily imagined that the four valves may be so connected that a single movement imparted to them should open one pair and close the other.

When the piston arrives at the bottom of the cylinder, a single motion in the contrary direction will evidently effect the object to be attained, that is to say, to open the lower steam-valve and upper exhaust-valve, and close the upper steam-valve and

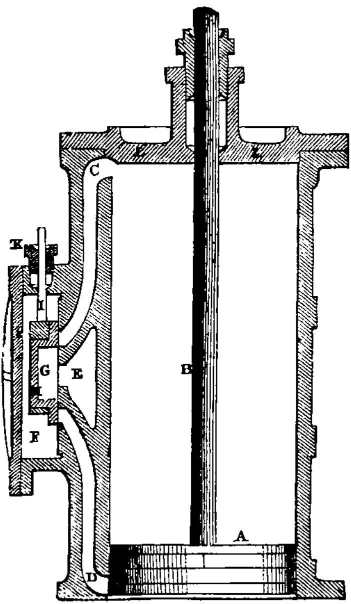


Fig. 6.

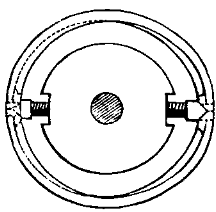


Fig. 7.

lower exhaust-valve. This will be better understood by reference to Figs. 6 and 7.

To render the engine self-acting, some contrivance must be adopted by which these valves will be regularly opened or shut by the action of some part of the engine itself.

The means generally adopted for opening and shutting valves and working slides is by what is called an eccentric, as seen in Fig. 8.

This consists of a circular plate of metal, *a a*, fixed

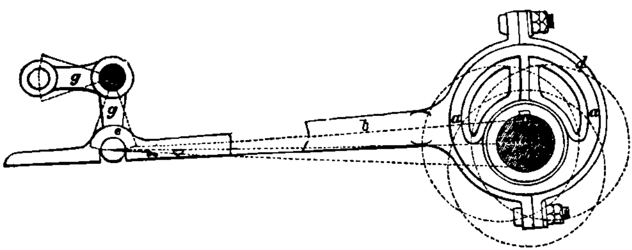


Fig. 8.

upon a shaft, *e*, at some distance from its geometrical centre. Round this eccentric point it is made to revolve, and in revolving it is evident that its geometrical centre revolving round its centre of motion will be thrown alternately to the right and left of such centre.

Round this circular disc is placed a ring, *d*, within which it is at liberty to turn, but not to turn the ring with it; the ring will consequently be thrown alternately to the left and right of the centre on which the eccentric plate is made to turn, and the throw or length of its play right and left will be equal to twice the distance of the geometrical centre of the disc to the centre on which it actually turns. To this ring is attached a bar, *b*.

As the centre is thrown alternately right and left of *e* by the revolution of the disc, the point *e* receives a horizontal motion, right and left, to a like extent. The motion is transmitted by means of the levers, *g g*, to the slides of the cylinder by the mechanical arrangement shown in the cut.

With whatever force the piston be impelled, the effects of that force will be augmented just in proportion to the amount of vacuum produced in that part of the cylinder towards which the piston is pressing. Now, if one cubic foot of steam be reconverted into cold water, it will be reduced to one cubic inch of liquid, and we shall get the entire cubic foot (minus one inch) of vacuum, and therefore for every cubic foot of steam in the cylinder, we shall have a cubic foot of vacuum, minus one cubic inch. It is this advantage that is sought to be obtained by using what are called condensing engines, and it is to the genius of Watt that the great difficulty of condensing the steam without cooling the cylinder has been overcome; for previous to his time (1763), the steam was condensed in the steam cylinder, which was consequently cooled down at every stroke of the engine. Watt's invention consisted in the producing an almost perfect vacuum without in the slightest degree lowering the temperature of the steam cylinder, and this he effected by placing near the cylinder another vessel submerged in cold water, and having a jet of cold water constantly playing within it. Whenever he desired to condense the steam in the cylinder, he opened the communication by a valve between this vessel and the cylinder, and immediately the steam, by its elastic force, rushed into this vessel and was instantly condensed, leaving in the cylinder an almost perfect vacuum, and at the same time exposing the cylinder to no cold which could in the slightest degree lower its temperature.

Now, the second vessel, or condenser, would in time become filled with water from the jet, and condensed steam, as well as air, which would enter in a fixed form in the water, and which would be liberated by the warmth of the steam condensed by the water. This air would, to a considerable extent, vitiate the vacuum in the condenser. These impediments were surmounted by the adjunct of a pump to the condenser, by which the water supplied by the jet and the condensed steam, as well as air, were constantly pumped out by an apparatus called the air-pump.

To prevent the water surrounding the condenser from becoming warm, there is placed a pump and waste-pipe—the pump for supplying cold water, which, by its superior gravity, sinks to the bottom of the cistern, and the waste-pipe to carry off the warm water, which, being lighter, rises to the top.

Having, by the means which we have described, produced a continual self-acting reciprocating action of the piston, the next thing is to apply that motion to the machinery required to be moved, and this is done by attaching it at once to a beam, called the working beam: this is supported on a fixed axis, and alternately vibrates upwards and downwards as it is moved by the action of the piston through the piston-rod.

Now, it is evident that the ends of the beam to which the piston would be attached could not move upwards and downwards in a straight line (as the piston-rod does), but must describe the arc of a circle, whose centre would be the axis upon which the beam vibrates.

The piston-rod, as we have before described, is an accurately turned bar of iron, working through the centre of the cylinder-cover, and kept securely in that position by the packing in the stuffing-box, and unable to swerve to the right or to the left; consequently, if the head of the piston-rod was fastened to the end of the beam, it would be strained and bent by the motion of the beam. To remedy this inconvenience, it is necessary to place between the end of the beam and the top of the piston-rod a piece of mechanism called the parallel motion, which accommodates the curvilinear motion of the one to the rectilinear motion of the other. This is formed in a variety of ways; but the most common is the arrangement invented and used by Mr. Watt, and is considered one of his brightest thoughts. It is a continuation of rods, so arranged and joined together that while one of their pivots is moved alternately in a circular arc, like the end of the beam, some point upon them will be moved alternately upwards and downwards in a straight line. This will be readily understood by reference to the plate.

As nearly all motions that are required for driving the machinery of mills are effected by the constant turning of a wheel upon a shaft, it is necessary now to convert this reciprocating motion in a straight line, to which we have now arrived, into, as nearly as possible, a continually acting rotatory one, and this is generally effected by another invention of Watt's, called a crank. This is an application of the ancient method of giving motion to the potter's lathe, the original inventor of which is unknown, and even the era of its introduction.

The crank is an arm attached generally to the centre of the wheel, which it turns in the same manner as the motion is imparted to a winch or windlass—a thing of such common application, that it can require no description here. As a matter of convenience, in those engines worked with a beam, there is interposed between the end of the beam and the crank a strongly formed bar of iron called the connecting-rod.

Having by the means we have briefly described now got a self-acting machine ready to apply to any purpose required, there remains only one other point necessary to be attended to—and that is of considerable importance—being the means by which the power we have got may be kept within bounds, when inclined to exert itself too much, or stimulated when inclined to flag; and it would be continually falling into the one error or the other, however well the machinery might be constructed, as the work it was employed to do might increase or decrease in load upon it. To remedy this defect, Mr. Watt adopted an ingenious contrivance which is now called the governor, shown in Fig. 9.

A similar irregularity to the one we have described, occurred in the motion of corn-mills, from the varying quantity of water or resistance. It had early exercised the ingenuity of millwrights to obtain some means by which its injurious effects could be obviated, and the means they adopted was attaching a couple of heavy balls to a jointed rod. These balls were made to revolve by being connected with the spindle or axis of the mill-runner, and the apparatus was called a lift-tenter. The centrifugal force of these balls when in motion either raised or lowered a stage in which the arbor of the spindle revolved, and brought the stones nearer, or removed them farther from, each other, as they might require to be adjusted. This most ingenious regulator Mr. Watt applied to regulate the opening and shutting of the throttle-valve of the steam-engine. Fig. 9 shows the manner in which this is effected. I I are two balls attached to two rods H G; when the balls separate so that the rods H G become more divergent, the arms H F open, and the pivots F separating, draw down the collar E, which slides on the spindle. When the balls, instead of diverging, approach each other, the arms H F also approach each other, and the collar E is lifted. Thus, as the balls, by the action of centrifugal force, diverge or contract towards the seat they occupy when

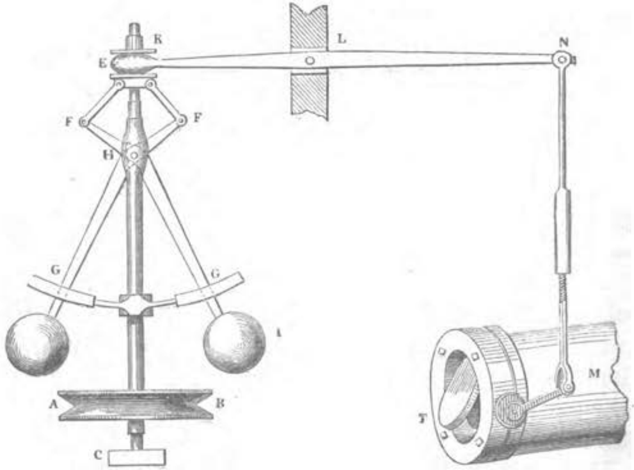


Fig. 9.

the engine is at rest, the collar E is raised or lowered by means of a lever, N L K, having a fork formed at one end, which receives the motion of the sliding collar E, and transmits it to the lever of the throttle-valve, as shown in the cut. A rotatory motion is given to the balls by a strap, gut-line, or gearing to the pulley A B (fixed upon the lower part of the spindle) from any convenient part of the machinery in motion.

As it is necessary that the boiler be supplied with water equal to that evaporated and consumed by the engine in the shape of steam, it is usual to employ the power of the engine to work pumps for that purpose. In condensing engines water is supplied to the boiler from the condenser, extracted by the action of the air-pump, as this water is considerably warmer than that drawn direct from the original source, and is of course a saving of so much heat.

As this supply of water requires to be merely regulated, a self-acting apparatus is attached to the boiler, but this arrangement is only applicable to low-pressure boilers, as the column of water or head would require to be inconveniently high to overcome the great pressure of the steam in the latter case. Therefore forcing or feed-pumps are attached to the engine and an arrangement made by which the driver can regulate the quantity supplied.

Formerly it was commonly thought that if water were heated nearly boiling hot it would save nearly the whole coal; but now everybody knows that the principal absorption of heat in turning water into steam is not providing the sensible heat which goes to make water feel hot, but in imparting the latent heat required to convert the liquid into a vaporous condition.

Steam Boilers.—But those who employ or are about to employ steam-engines should possess some knowledge of the boilers, for the generation of steam to supply these engines is of the first importance. Farmers will readily understand this when they consider that it is the boiler that will more resemble the horse than the engine, for it is the boiler that has to be fed with fuel, and whose goodness or badness will render the application of steam-power economical or the reverse; it is the boiler that will require the more special care of its superintendent, and which will soonest show the effect of bad treatment; and it is this same boiler that constitutes all the danger of using steam-power, for if an improper one, or a bad one, its owner may be informed of the fact by a terrible explosion.

The boiler is the real test of the power of any engine. The evaporative power of the boiler and the strength of the boiler limit the power of the engine. The size of the cylinder (within reasonable limits) has positively nothing to do with the power that an engine can exert.

"The best makers give 20 ft. of heating surface for each nominal horse-power, or 200 ft. to a 10-horse engine; and they would put on to it a 10-in. cylinder. Some makers, however, instead of giving 200 ft., would only give 140, or 130, or 120, and some even as low as 100 ft. of 'heating' surface for a 10-horse engine, and yet they will put the same sized cylinder (10-in.) on to these small boilers.

"Suppose then a farmer, knowing nothing about engines, bought from one of these unscrupulous makers a machine called a '10-horse engine,' with a 10-in. cylinder, and 120 ft. of heating surface in the boiler, and suppose the price was £5 or £10 less than the price of a 10-horse engine by one of the best makers, he would think he had done a clever thing; yet the engine he had bought would only do as much work as a 6-horse engine by a first-class maker."

It would be well, therefore, if purchasers and manufacturers would describe engines exactly according to their actual—not *nominal*—horse-power. A horse-power, as every one knows, was settled by Watt to be equivalent to 33,000 lbs. lifted one foot high per minute; and this is the real and only standard. If, then, a manufacturer declares his engines to be 10-horse power, it ought to be able to raise 300,000 lbs. (about 150 tons) through a foot in a minute of time, or, what is precisely the same thing, one ton through 150 ft., or 1 cwt. through twenty times that distance, or 3,000 ft.

The construction of the boiler, and the necessary strength it should have given to it, must be left to the maker, but it would always be well if the farmer required a written guarantee when he purchased it that it has been proved to a certain pressure without showing symptoms of any weakness; but the fact of its having been thus tested must not induce those who use it to neglect any precaution for safely working it; for the tensile strain that good wrought iron is capable of undergoing without rupture is so enormous that it will rarely give way to pressure fairly applied, as it is in the usual manner of testing, yet sometimes they explode the first time they have been used after having been so tested.

There are only two ways in which a boiler can be caused to explode, or as it is commonly called, burst. One is by gradually increasing the power of the steam in the ordinary way. It having no means of egress from the boiler it gradually increases until the plates and rivets are no longer able to bear it; a rupture of the weakest part must of course then take place. The other is when, from any cause, so sudden an increase of pressure takes place that the ordinary means provided for its liberation (as the safety-valves, &c.) are unable to act in a sufficiently rapid manner to prevent the strain the boiler is required (though only for a moment) to bear; it is to this last cause that most explosions are due; and the greatest care must be taken to prevent the circumstances arising which produce such terrible disasters.

If burnt boilers and boiler explosions are to be prevented, it is necessary that the proper level of the water in the boiler should be cautiously maintained, and especially that any lowering thereof, by neglect or accident, should not only be indicated, but remedied at once. This is an office that is fulfilled automatically by Bailey's (Ashcroft's patent) Low-water Detector and Alarm (Fig. 10), which, in its operation, is independent of mechanism, of valves, springs, floats, cranks, or other moving parts, being efficient and reliable solely through the natural effects of heat and gravitation. Its action depends entirely on a fusible plug, made of metal or alloy, which melts at the boiling point of water, or the ordinary temperature of steam, under the pressure of one atmosphere, *i.e.* at 212 deg. F. This fusible disc is so placed, that under the usual conditions it is accessible only to water having a temperature below its melting point; and whenever the water in the boiler falls below the proper level, immediate access is given to the steam, which at once melts the plugs and escapes, blowing the whistle, and sounding an alarm. This useful appliance has also a metal tube connected to the boiler by a stop-valve (this always being locked when open), and carrying an air-chamber with a half-

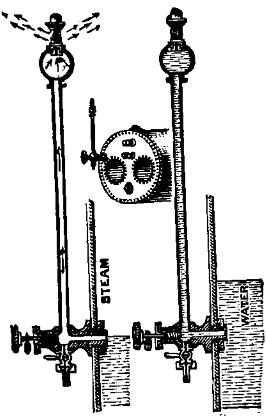


Fig. 10.

inch fusible disc, secured to its seat by an union with a whistle on its stem, and capable of bearing a pressure of 250 lbs.

The fusible plug has been applied in many other ways, but with the disadvantage of complete emptying of the boiler when requiring renewal—a manifest drawback to general use, and an objection to which the arrangement here shown is not liable, as by closing the connecting cock—accessible only with the key—and unscrewing the whistle and union joint, a fresh disc can be put in the seating, without emptying the boiler; and until this be done the whistle will continue to be sounded by the escaping steam. Thus not only is accident or injury prevented, but neglect infallibly detected by the principal or his representative keeping the key.

"*Expanding*" *Steam-Engines.*—"No farmer nowadays ought to buy any other engine than an 'expanding' engine, one in whicb, by means of a separate cut-off slide, the expansive power of the steam can be utilised.

"The enormous additional power to be gained out of steam simply by allowing it to expand is quite astonishing. An ordinary low-pressure farm engine is usually worked with about 50 lbs. on the safety-valve, and the slide-valve is so arranged in most of them that it does not shut off the steam until about $\frac{7}{8}$ths of the stroke has been completed. Now, if a cubic foot of water be raised into steam at that pressure, and be passed through such an engine, it would raise 3,312,288 lbs. 1 ft. high, if there were no waste and no friction. But if, instead of cutting off only at $\frac{7}{8}$ths of the stroke, we arrange our engine with a separate cut-off slide, which allows us to shut off the supply of steam when only one-third of the stroke is made, then a cubic ft. of water raised into steam at the same pressure (50 lbs. above the atmosphere), and passed through such an engine, would raise 5,558,400 lbs. 1 ft. high, if there were no waste and no friction. But, suppose again, instead of limiting ourselves to 50 lbs. pressure we make a boiler that will bear 120 lbs. on the safety-valve, and instead of cutting off at one-third suppose we cut off at one-sixth of the stroke, then a cubic ft. of water raised into steam at that pressure (120 lbs.), and passed through such an engine, would raise 8,438,109 lbs. 1 ft. high, if there were no waste and no friction.

"It is well known that the quantity of coal requisite to turn a cubic ft. of water into steam is as nearly as possible the same at all pressures. What, then, does this amount to? Why that the same quantity of water and the same quantity of coal used in an expanding engine will raise 8,438,109 lbs. 1 ft. high, whereas in one of our ordinary engines it would only raise 3,312,288 lbs. 1 ft. high.

"These figures, taken in the inverse ratio, represent the proportionate quantity of water and coal which each engine would require to do a certain amount of work. Suppose, for instance, we had a certain piece of work to do, which with an ordinary portable engine we knew took 1,000 gals. of water and 1,500 lbs. of coal to do, then, if we set an expanding engine to it, working on 120 lbs. on the safety-valve, and cutting off at one-sixth of the stroke, we should only require 392 gals. of water and 573 lbs. of coal to perform the same work!"

It need scarcely be said that a boiler properly designed for 120 lbs. steam, or even a higher pressure, is as safe as one designed with smaller margins of safety for 50 lbs. steam. The prejudices against high-pressure steam-engines are happily disappearing.

In old boilers the consumption of fuel is never less than 5 or 6 lbs. per effective horse-power; but by working steam more expansively it has been reduced in improved engines to 2 lbs. Yet, comparing this with the total amount of energy of 2 lbs. of coal, it will be found that not a tenth part of the power is obtained which that amount of coal would theoretically call into action. The theoretical energy of 1 lb. of coal is stated by Sir J. Hawkshaw as follows: The proportions of heat expended in generating saturated steam at 212° Fahr., and at 14·7 lbs. pressure per square in., from water at 212° are :—

	Units of heat.	Mechanical equivalent in foot lbs.
1. In the formation of steam	892·8	689,242
2. In resisting the incumbent pressure of 14·7 lbs. per square inch. . . .	72·3	55,815
	965·1	745,057

One pound of Welsh coal will theoretically evaporate 15 lbs. of water at 212° to steam at 212°. Therefore the full theoretical value of the combustion of 2 lbs. of Welsh coal is—

$$2 \times 15 \times 745{,}057 \text{ foot pounds,}$$

or,

$$\frac{2 \times 15 \times 745{,}057}{60 \times 33{,}000} \text{ horse-power, if consumed in 1 hour.}$$
$$= 11{\cdot}2 \text{ horse-power.}$$

As the consumption of coal per effective horse-power in a good engine is 2 lbs., the power obtained is to the whole theoretical power as 1 is to 11. The average engine uses very much more coal.

Compound Engines.—The example set by Messrs. R. Garrett and Sons at Carlisle in 1880 is being followed by many other makers of agricultural engines, who are now turning out compound engines.

The judges in their report to the Royal Agricultural Society in 1880 say, "The higher the boiler pressure the earlier the steam may be cut off with advantage, and the greater the economy resulting from expansion. The gear, however, necessary for great expansion in a single cylinder is always complicated in its details, it easily gets out of adjustment, and it is rarely equal in its action at both ends of the cylinder. The compound engine with the addition of an extra cylinder enables us to get all the expansion which we desire with simple valve gear, and the losses from cooling are further neutralised by dividing the extreme range of temperature between two cylinders. The steam is admitted first to the small high-pressure cylinder to do work against its piston, and thence is exhausted at a medium pressure, then does about an equal amount of work again in the low-pressure cylinder of a larger diameter, being finally exhausted into the open air at a pressure slightly above that of the atmosphere. The general result is that by adding a small amount to the cylinder-weight of extra piston, a slide-valve, and other gear of a simple character, we can do the same work as before with considerably less steam; and as the steam produced in a given boiler is proportionate to the coal which provides the heat for producing it, the coal used, as well as the feed-water required, are reduced in exactly the same proportions.

"The most convenient sized engine for almost any sized farm would be an 8-horse boiler (160 square ft. of heating surface) with two 6-horse cylinders (8 in.

diameter), fitted with separate expansive slides and a coupling on the crank-shaft. Such an engine would do as much work if wanted as could be got out of a nominal 20-horse engine of the usual non-expanding pattern, and yet by uncoupling one cylinder it could be worked down as low as any ordinary 6-horse engine. It could, in fact, be made to do the work of a single horse or of forty horses at pleasure, and, if a portable engine, it ought not to cost more than a 10-horse double cylinder engine of the present pattern, say about £270; or if a traction engine, then the cost would be about the same as a 10-horse road locomotive, say about £400."

Stationary Engines.—Where there is much regular

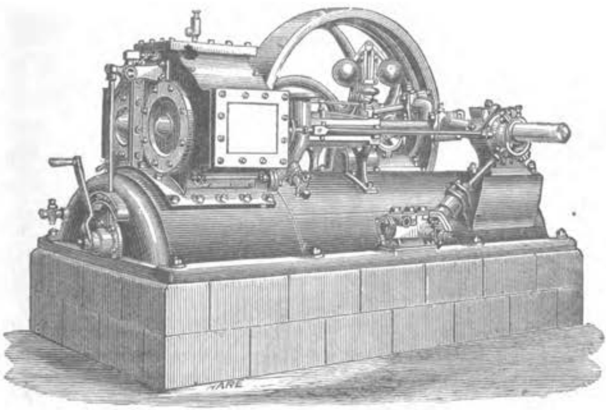


Fig. 11.

barn work, either in threshing, grinding, or food preparing, a small stationary engine will recommend itself, but it is only on large farms that fixed motive power is required for driving machinery.

For this purpose Garratt's Horizontal Fixed Steam-engine, with compound cylinders (Fig. 11) will be found very suitable. The engine and boiler are combined, and the latter may be either multitubular or Cornish in principle, though the multitubular boiler is recommended where economy of fuel is essential, and also because it requires little or no fixing.

Portable Engines.—An engine which is merely a portable and not a traction engine is now of comparatively limited value on the farm. It answers for steam threshing, and even for steam cultivating in the roundabout system; but in either of these cases it has to be moved to and fro by horses, and for all other purposes it may as well be a stationary engine.

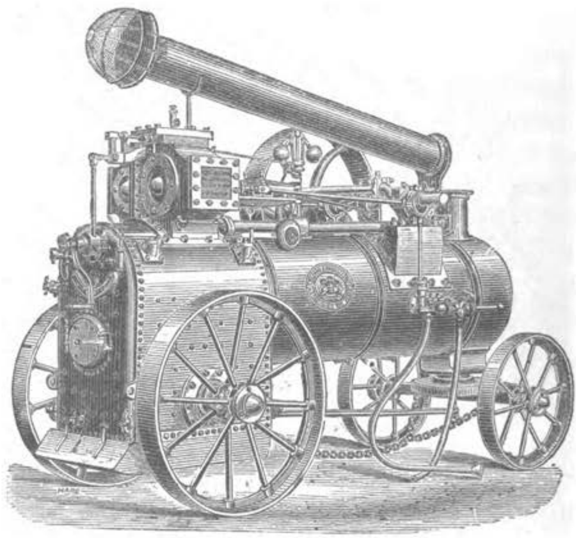


Fig. 12.

Fig. 12 is an illustration of Garrett's Compound Portable Engine.

Vertical Engines.—For light work the old horizontal fixed engine and separate Cornish boiler is now almost entirely superseded by small-power vertical engines and

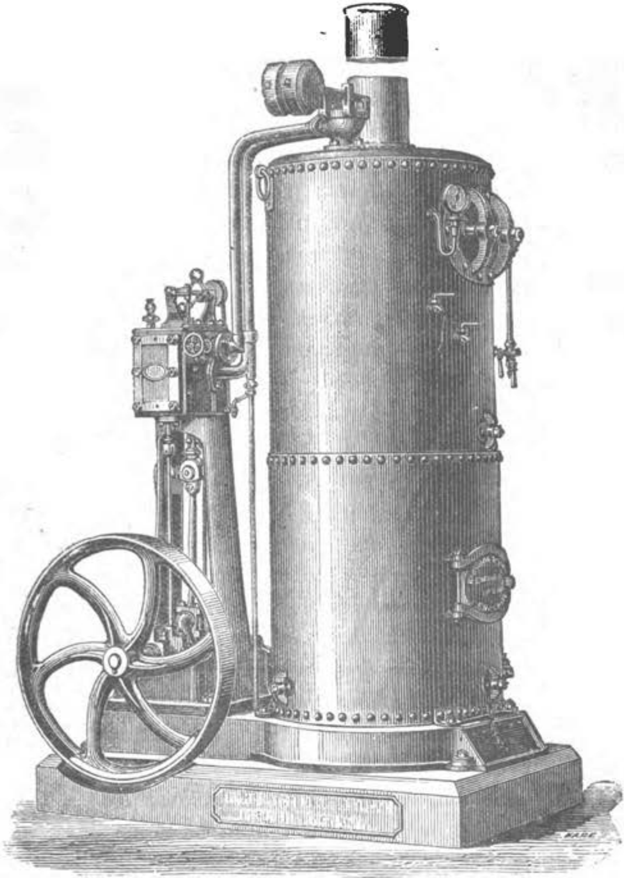


Fig. 13.

boilers combined. Among the advantages possessed by this type of engine over the old sorts are the saving of time and expense in fixing and greater economy in fuel. They are also cheaper in first cost, and less expensive to feed and maintain.

One of Ransome, Head, and Jefferies' Vertical Steam-engines, with Cochrane's Patent Multitubular Vertical Boiler, is shown in Fig. 13. These engines are especially economical in consumption of fuel, being fitted with a number of tubes similar to the boilers of locomotive or portable engines, thus largely increasing the heating surface and preventing waste of heat directly up the chimney; they consequently generate steam rapidly with great economy of fuel, and are recommended where fuel is scarce and expensive. The tubes are perfectly easy of access for cleaning and repairs, both inside and outside. The engine and boiler are mounted on a strong cast-iron bed-plate, which forms an ash-pan and also a tank for the feed-water. The boiler is fitted with double safety-valves, steam pressure-gauge, glass water-gauge, two gauge-cocks, blow-off cock, and usual firing tools and accessories. The engine is mounted on wheels when required.

At the York show of the Royal Agricultural Society, in July last, Messrs. Riches and Watts, of Norwich, exhibited an engine of this class, which attracted a good deal of attention. This was a compound condensing engine with boiler combined. Fig. 14 is an illustration. The cylinders are as shown, "tandem," with the small cylinder at top, fitted with an intermediate stuffing-box, of a form which the makers have used for ordinary inverted cylinders for thirty years. The valves are simple three-ported ones, worked from an eccentric on either side of the crank-throw, the arrangement being very simple and easy to get at. The air-pump is single-acting, and placed inside the condenser, worked by gearing about one to one and a-half of engine. The engine can in a few minutes be converted into a non-condensing compound by simply disengaging the exhaust pipe and fixing another pipe that leads the exhaust into the chimney, in case the supply of water failed at any time. The feed-pump is worked from an eccentric cast on the same cog-wheel which works the air-pump and feeds from the hot-well on top of condenser.

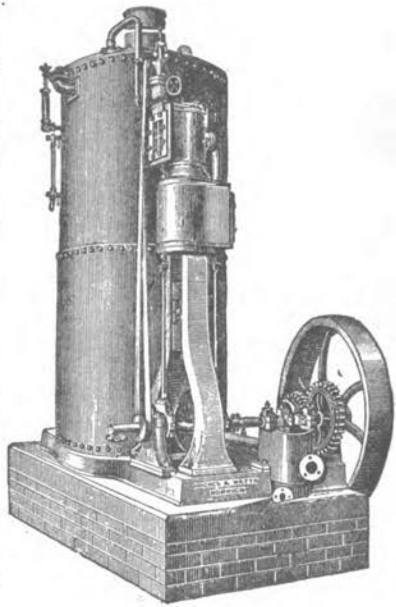


Fig. 14.

The engine exhibited was of 4-horse power nominal, working to 12-horse power indicated, with a consumption of fuel, we are informed, of about 3½ lbs. per indicated horse-power per hour.

Agricultural Locomotive Engines.—For working threshing machinery, for steam cultivation, sawing, pumping, &c., for removing agricultural produce, and in fact for all purposes to which steam can be applied as a motive power in farm work, the agricultural locomotive is far better adapted than a mere portable engine.

Fig. 15 is an engraving of one of Ransome, Head, and Jefferies' agricultural locomotive engines. These

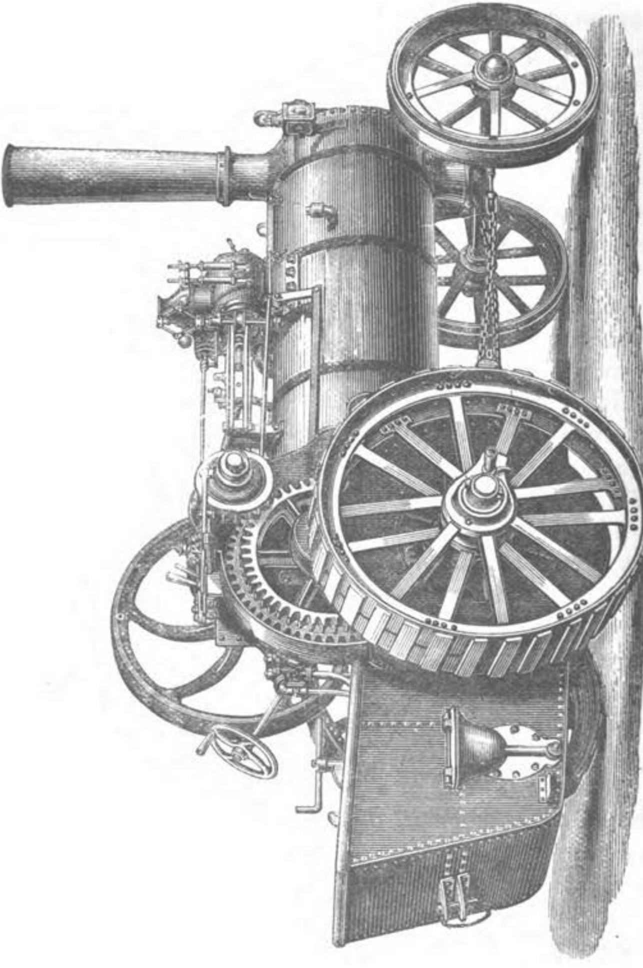


Fig. 15.

engines are made in two sizes, viz. 6 and 8 horse-power, and are arranged to travel at two different speeds, viz., about 1½ and 3 miles per hour.

They are constructed from the newest designs, and the general arrangement is the result of a long and varied experience with this class of machinery.

A winding drum working on the main axle can be fitted to these engines; and by means of a wire rope the whole power of the engine can be brought to bear upon the threshing machine, so as to draw it out of any extra difficult situation while the engine remains stationary. This is an extremely useful addition, as all those who are accustomed to them will see at once.

These engines can be fitted with double slides when required, so as to make full use of the expansive power of the steam. They can also be fitted with a new patent automatic governor, acting direct on the second expansion-slide by means of a link motion. This is a very valuable arrangement when an engine is required to drive machinery in which the load is constantly varying, at one time taking the full power of the engine and at others but a small portion of it. For sawing machinery, crushing-mills, &c., it is very useful, as only the exact amount of steam required at each instant is admitted into the cylinder, and a perfectly uniform speed is always maintained.

The Sutherland engine (Fig. 16) is a 4-horse-power locomotive, designed by Messrs. Fowler and Co. to supply a want which has long been felt by the users of our heavier engines for agricultural purposes. While the heavy engines have been proved to do the heavier work economically, they have been found badly adapted for the lighter operations, such as rolling, reaping, and carting on the farm; and hence the necessity has arisen to keep a larger number of horses than is consistent with a good system of steam culture.

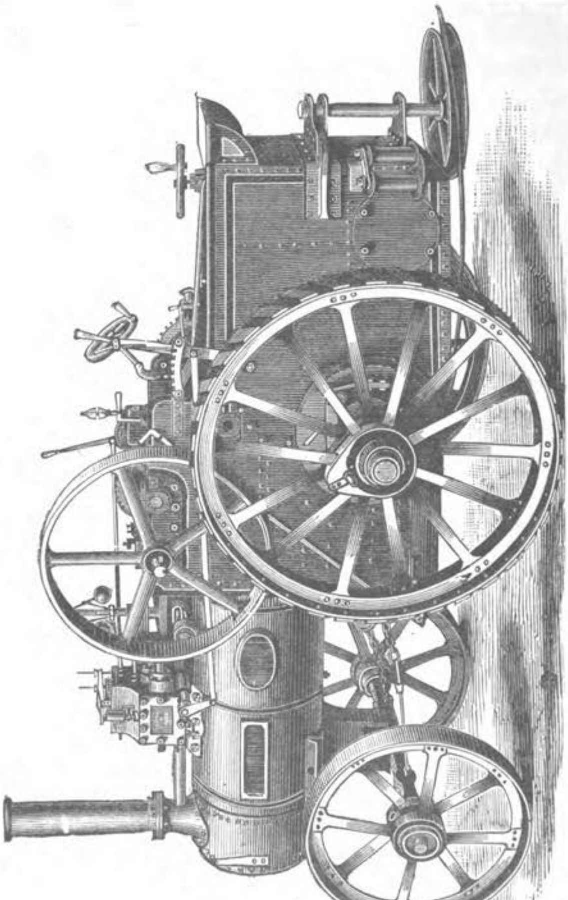


Fig. 16.

It is a patented combination of parts suitable for the purposes just mentioned, and has proved a complete success. It will pull 6 tons on the road; it will reap 3 acres per hour; it will roll 30 acres per day; it can be used for pulling a three-furrow plough on level sandy land; it will pull home the turnips and corn, and take out the dung without injury to the land; it will drive a thresher, grinder, chaffer, and pulper. To convert it into a land roller, a series of widening rings are attached to the hind wheels, and a roller of sufficient width to cover the space between the hind wheels takes the place of the fore wheels. The engine will then roll a breadth of from 8 to 10 feet. When used as a reaper, a knife-bar and delivery reel driven off the crank-shaft, are made to project from behind the traction wheel without disengaging the roller rings. The reaping and rolling in this way are secured by one operation. This engine is capable of going over any land, however soft, without injury.

Straw-burning Engines.—In field threshing by steam power, it is of the utmost importance, in countries where coal and wood are scarce and dear, that the engine employed should be one constructed to burn straw and other vegetable refuse. Fig. 17 is a section showing the working of R. Garrett and Sons' portable straw burning engine.

The straw is introduced by means of a fork in light parcels or wisps, where it is thoroughly dried before ignition, and each wisp is pushed forward by its successor into the fire-grate, where combustion instantaneously takes place; great economy of fuel is effected by the perfect drying of the straw above described, and also and consequently great ease of stoking, which is greatly enhanced by the perfect readiness of access to the grate and the tubes of the boiler, through the hopper and the ordinary fire-door placed above it.

Every engine of this class is provided with an ordinary fire-door for burning coal in addition to the hopper for straw-burning, as also with a set of the ordinary fire-bars and suitable bearers, and as the grate area is contracted, as shown in sectional view, by means of the patent combustion chamber, to the dimensions adopted for ordinary coal-burning boilers, whilst the heating surface is increased, and the combustion of the gases is

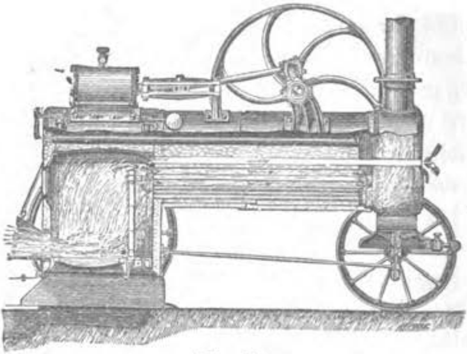


Fig. 17.

more perfect, it follows that the straw-burning boilers are the more economical in the consumption of coal, whilst in respect of weight and portability the disadvantages are not material.

Many experiments have been tried as to the comparative values of straw and coal for fuel purposes in threshing by steam. These trials have demonstrated 3·25 to 3·75 lbs. of average dry wheat straw will evaporate the same amount of water in the same time as 1 lb. of good coal in the most modern boiler.

The amount of straw grown per acre varies very much, but in England the average may be taken at 30 cwt. per acre for wheat straw, or say 3,300 lbs.

per acre, and is worth about 30s. per ton on the farm. Consequently, the value of straw produced per acre would be about 44s.

Now, if we take the value of 1 ton of coal, at the farm, in England, at about 20s., and admit the proportion of 3·50 lbs. of straw to 1 lb. of coal, we shall arrive at the following conclusion: 3,300 lbs. cost about 44s. equals 943 lbs. of coal, cost 8s. 6d. From this comparison we find that the commercial value of straw in proportion to coal is about as one to five. It must not be supposed, however, that this comparison is applicable to every district. There are countries where the straw is of no value except for fuel, and districts where coal could hardly be obtained at any price.

The average proportion of calorific effect found by practice to exist between coal and other products used as fuel on the farm is, according to experiments conducted by Mr. Head, of Ransomes, Head, and Jefferies, as follows:—

1 lb. of good coal will evaporate 8 lbs. of water in an ordinary tubular boiler.
2 lbs. of dry peat will evaporate 8 lbs. of water in an ordinary tubular boiler.
2·25 to 2·30 lbs. of dry wood will evaporate 8 lbs. of water in an ordinary tubular boiler.
2·75 to 3 lbs. of cotton stalks or brushwood will evaporate 8 lbs. of water in an ordinary tubular boiler.
3·25 to 3·75 lbs of wheat or barley-straw will evaporate 8 lbs. of water in an ordinary tubular boiler.

Various apparatus have been designed for arresting the exit of sparks in locomotive and portable engines which work in places surrounded with inflammable substances, such as straw, brushwood, grasses, &c. Some consist simply of a cage or collector of the sparks, whilst in others water is used in order to extinguish the incandescent pieces of fuel which are blown through the tubes into the smoke-box.

Fig. 18 illustrates Graham's Spark Arrester, now being applied by Messrs. R. Garrett and Sons to their portable engines. It is thoroughly efficient and reliable, the parts being so proportioned that, though it is impossible for hot sparks to find exit, the draught

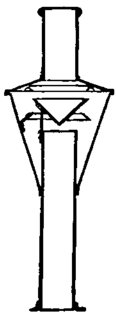


Fig. 18.

through the fire is not appreciably reduced. The arrangement consists mainly of conical and annular boffle plates, made of light malleable iron, and fixed within a conical enlargement of the chimney. The cooled sparks which collect in the open space below the inverted cone are from time to time removed through the small hand-holes made for that purpose.

CHAPTER IV.

THE GAS-ENGINE.

THE gas-engine is pre-eminently a *secondary* power, for the reason that a portion of the latent force of the fuel has first to be converted into gas, and subsequently mixed with air, before it can be applied to produce motive power. The loss by this method is far greater than with the steam-engine, and may chiefly be summarised as follows:—

1. The *total loss of fuel* used to heat the gas retorts and calcine the coal from which the gas is extracted.

2. The loss of heat generated in the cylinder of the gas-engine, and taken off by the flow of water surrounding it.

3. The loss of heat after the gas and air have exploded, and performed their work upon the piston of the engine.

Notwithstanding, however, the greatly increased cost of working a gas-engine, it is in some cases (for small-power engines) preferable to steam on account of its greater safety and cleanliness. It must also be remembered that the gas-engine will start at full power on the gas being lit; and it requires no boiler, and does not call for constant attendance.

The "Ord" Patent Gas-Engine (Fig. 19) is a most useful and economical small-power engine.

The engraving and annexed letter-press will make the "Ord" engine understood.

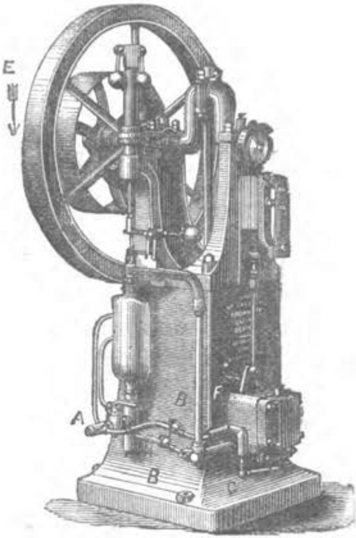


Fig. 19.

A, Main gas tap, to be turned on full at starting; B B, small gas taps, the lower one to be turned on about half, the upper one to be turned on full at starting, and then, when the engine is working properly, both these taps may be partially closed; C, burner, inside a hollow cone, at which gas must be lighted after opening B B; D, valve, to be opened a little at starting, and regulated as the engine commences working; E, fly-wheel, to be pulled briskly round in the direction of the arrow; F, gauge-cock, below which the water in tank must not be allowed to fall; G, cock, for letting water out of tank if required.

Power.	Revolutions per Minute.	Approximate Cost of Gas per Hour.	Price.	Price of Water Cistern.
Two-man . .	160	$\frac{3}{4}$d.	£35	22/
Half-horse . .	160	1d.	£50	30/
One-horse . .	160	$1\frac{1}{2}$d.	£65	50/

CHAPTER V.

HOT-AIR ENGINES.

Hot-air or caloric engines are very successful substitutes for steam or gas-engines. As compared with steam-engines they have several advantages for agricultural purposes. No water is required: no boiler: no pipe connections: no skilled labour: and explosions are impossible.

The motive power in these engines is atmospheric air, which is forced by a pump into a hermetically sealed retort or generator, where it becomes heated and expanded. The pressure thus created is admitted to a cylinder, and operates a piston after the manner of a steam-engine. The heated air is discharged from an exhaust pipe, free from smoke and perfectly invisible. By a governor arrangement the "cut off" can be regulated, and the air caused to pass more or less through the incandescent fuel, or in the space above the fire, so that whilst the nominal speed of the engine is maintained, the fuel is only consumed in direct proportion to the power being developed by the engine. Additional fuel is supplied from a fuel chamber at the top of the generator, and delivered to the fire by a valve, without loss of pressure or interference with the running of the engine. The fire can be lighted and the engine started to work in about half an hour, and only a trifling amount of lubrication is necessary.

The "Buckett" caloric engine (Fig. 20) is one of the most successful engines of this class. It is a single cylinder vertical engine, and its simplicity and few working parts render any elaborate instructions for its working unnecessary.

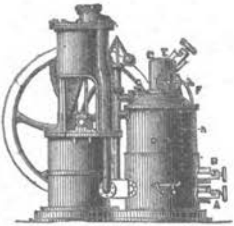


Fig. 20.

To prepare the engine for starting, remove the doors A, B, C, and clear out from A the ashes of the previous day's working. Light a fire in the ordinary manner on the top of the grate bars, within the opening B, and place a length of stove pipe over the opening C, so as to create a draught. When the fire is thoroughly alight, remove the pipe and close all the doors A, B, C, and the engine is then ready for being started. To do this, in the case of a small engine, revolve the fly-wheel a few times; or, with a larger engine, give a few strokes of a hand pump provided with the engine for the purpose. This serves to give the first charge of air to the generator, and, a pressure being created, the engine will commence to work, and will afterwards continue to supply itself with the necessary complement of air with each stroke. Use a small quantity of *tallow* for lubricating the working surfaces of the cylinder and piston. *Oil* should not be used for this purpose, on account of its tendency to cake or incrustate by the heat; but the bearings and other working parts can be lubricated with oil in the ordinary manner. It is not necessary to feed the generator D with fuel at very frequent intervals, nor is there any advantage in using a quantity beyond that stated to be necessary to produce the power required. When the work of the engine is required to be uniform throughout the day, the time of feeding and amount of the charge should be regular. A very short experience will enable the attendant to regulate the interval and amount of feed to suit circumstances.

To charge the generator D, remove the door E, place the fuel in the opening and close the door. Turn on the cock F, to allow a small quantity of the compressed air to pass into the fuel chamber G; this equalises the pressure on both sides of a fuel valve within the chamber, so that upon raising the chain H the valve can descend and allow the fuel to fall upon the fire below. The chain can then be drawn down and the cock turned off, the pressure on the underside of the valve retaining it firmly against its seating. When this is done (which need only occupy two minutes), the engine can be left to itself, without fear of trouble or explosion.

Comparative cost of working a gas, steam, and "Buckett" caloric engine respectively, as certified by Messrs. Field, Field, and Cotton, consulting engineers. *Example* :—A 12-horse power engine, working fully up to that power 10 hours per day for 300 working days per annum.

	£	s.	d.
Steam-Engine.—6 lbs. of best steam coal per horse-power per hour, 6 × 12 × 10 × 300 = 216,000 lbs. = say, $96\frac{1}{2}$ tons at 18s.	86	17	0
Gas-Engine.—The best gas-engine is stated to consume 23 cubic feet of gas per horse-power per hour, 23 × 12 × 10 × 300 = 828,000 cubic ft. at the average all-England rate of, say, 3s. 9d. per ft. .	155	5	0
The "Buckett" Caloric Engine.—Consumption, $2\frac{1}{2}$ lbs. ordinary gas coke per horse-power per hour, $2\frac{1}{2}$ × 12 × 10 × 300 = 90,000 lbs., which, at 14 cwt. per chaldron = say, 58 chaldrons at 12s. .	34	16	0

Bailey's Patent Hot-air Engines, on Lehmann's system, are also much used for power as well as pumping, such as chaff-cutting, churning, grinding, and crushing, also for pumping and power combined, and for general agricultural, industrial, and domestic engineering purposes.

Fig. 21 shows one of Bailey's horizontal hot-air "Driving" engines, working a chaff-cutter.

This engine consists of a cylinder closed at one end by a steel pot, and at the other by a piston. The steel pot is fixed within the stove, whilst the cylinder is

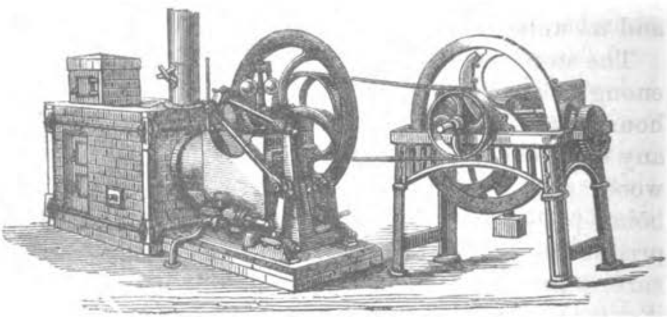


Fig. 21.

surrounded by a water-jacket. The engine is fitted with a speed-governor, which may be adjusted by hand to vary the speed if required. Once set in motion it requires no attention beyond oiling once or twice a day.

The engine is kept solely at work by the alternate heating and cooling of the air within the cylinder; the air being caused to travel backwards and forwards by a loose-fitting piston within, which is worked by the engine from the outside by means of a piston-rod passing through the front or driving piston. The air being used over and over again there is thus no exhaust and consequent smell of burning oils, &c., and there are no valves whatever to wear out or stick fast, causing expense and stoppages.

The cooling of the front end is done by a separate water vessel, connected to the "jacket" by water circulating pipes, or a small stream of fresh water under pressure is run through whilst the engine is working. In the case of circulating pipes, the hot water may be stored in a barrel or tank for domestic use. Thus the cooling requires no special attention, and no water is wasted.

The stove is provided with a roomy fireplace, holding enough fuel to keep the engine going from 3 to 6 hours without stoking. The furnace will burn almost any combustible material convenient at hand, such as wood, peat, riddled cinders; coal-gas coke, however, being preferable, as being the most economical fuel for producing and maintaining a gentle and even temperature, which is essential in working this engine; and as it consumes its own smoke it needs no attention during the intervals of firing.

The cost of working the smaller sizes rarely exceeds one penny per day.

Bailey's Caloric Pumping Engine, the "vertical" pattern, is shown in Fig. 22.

This new caloric engine has a metallic piston; the pump valves are easy to examine, and the number of working parts is reduced to a minimum, with the utmost simplicity of arrangement.

These engines are used to drive existing pumping machinery, such as is used in irrigation and kindred work. They are also employed for driving churns, and for dairy work generally, and for agricultural power requirements they are unsurpassed, and they are

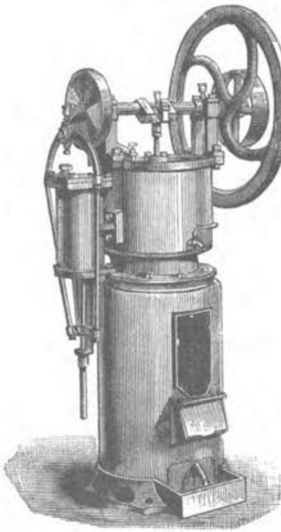


Fig. 22.

absolutely free from danger and are worked with the minimum of cost.

CHAPTER VI.

ELECTRIC POWER.

IT has long been predicted that electricity would become the great motor of the future. But even in the light of recent successful experiments with it, we are perhaps little able to fully comprehend the future uses of this agent as a means of transmitting power and of working machines.

Many years have elapsed since sanguine electricians declared that a few plates or coils of metal and a few bottles of acid were all that ought to be necessary to drive a plough through the soil, a spindle giving motion to factory machines, a railway train across a continent, or a ship across the ocean. Everybody said that it could be done and ought to be done, but they were not so clear as to how it was to be done and made to pay.

Sir William Siemens even promised an unlimited supply of force from the falls of Niagara, and was bold enough to prophesy that not only would it some day be used to propel all the spindles of New England, but be imported, as we import wheat and pork, for the supply of the Lancashire mills when the English coal-fields became exhausted; and, indeed, so much has been heard of the possibility of using not only the falls of Niagara but, to come nearer home, the tidal fall of the Severn and other sources of water-power available in our midst, that we may well wonder why, if the schemes are so feasible, no endeavour has yet been made to utilise the vast power which is perpetually running to waste.

The cardinal difficulty has been that already indicated, of cost in proportion to result. But it would be rash in the extreme to attempt to prescribe limits to the potent agent which is so easy of transmission, and which can now be carried about stored in boxes and applied wherever force is required, either to drive plough, car, or ship, to pump a marsh or drive a pile.

The time may come when a roaring torrent on a bleak hill-side will be more valuable than a manor in the rich valley through which it flows. Then the Highlands of Scotland, the fells of Norway, the becks of Cumberland, and the waterfall districts of Wales will be the great manufacturing centres of the world; and it is even possible, should it be demonstrated that the electric-borne force is cheaper than that obtained by burning coal, that this extraordinary social revolution may be nearer at hand than is at present dreamt of.

As a means of transmitting power to a distance, the electric current has now entered the lists in competition with compressed air, the hydraulic accumulator, and the quick running rope, as used at Schaffhausen, to utilise the power of the Rhine fall.

It is estimated by Sir William Siemens that the transformation of electrical into mechanical energy can be accomplished with no further loss than is due to such incidental causes as friction and the heating of wires. These, in a properly designed dynamo-electric machine, do not exceed 10 per cent., as shown by

Dr. John Hopkinson; and, judging from recent experiments, a still nearer approach to ultimate perfection is attainable. Adhering, however, to Dr. Hopkinson's determination for safety's sake, and assuming the same percentage in reconverting the current into mechanical effects, a total loss of 19 per cent. results. To this loss must be added that through electrical resistance in the connecting line wires, which depends upon the length and conductivity, and that due to heating by friction of the machine. Taking these as being equal to the internal losses incurred in the double process of conversion, there remains a useful effect of 100—38 = 62 per cent., attainable at a distance, which agrees with experimental results, although in actual practice it would not perhaps be safe at present to expect more than 50 per cent. of ultimate useful effect, to allow for all mechanical losses.

In using compressed air or water for the transmission of power, the loss cannot be taken at less than 50 per cent., and as it depends upon fluid resistance, it increases with more rapidity than in the case of electricity. Taking the loss of effect in all cases at 50 per cent., electric transmission presents the advantage that an insulated wire does the work of a pipe capable of withstanding high internal pressure, which latter must be more costly to put down and to maintain. A second metallic conductor is required, however, to complete the electrical circuit, as the conducting power of the earth alone is found unreliable for passing quantity currents, owing to the effects of polarisation; but as this second conductor need not be insulated, water or gas-pipes, railway metals or fencing wire may be called into requisition for the purpose. The small space occupied by the electro-motor, its high working speed, and the absence of waste products render it specially available for the general distribution of power to light machinery of every description. A loss of effect of 50 per cent. does not stand in the way of such applications, for it must be remembered that a powerful central engine, of best construction, produces motive power with a consumption of 2 lbs. of coal per horse-power per hour; whereas small engines distributed over a district would consume not less than 5 lbs. We thus see that there is an advantage in favour of electric transmission as regards fuel, independently of the saving of labour and other collateral benefits.

The recent opening of the Portrush Electric Railway, practically the first of its kind, must be regarded as an event of considerable importance, not only in the history of Ireland but in the progress of electrical industry. Coupled with the remarkable results recently achieved at Grenoble by M. Marcel Desprez, it suggests great possibilities for the future, since it is now proved to demonstration that not only can force be carried by means of the electric fluid, but that the motive energy can be generated at a distance and applied directly where it happens to be required. Several months ago M. Desprez conveyed a ten-horse power through a wire nearly 23 miles long. The result was, however, only obtained by a large expenditure of steam-power in generating the force.

More recently he has been successful in proving that by the utilisation of the waterfalls running to waste, power enough could be obtained to make the new method of working machinery and supplying light perfectly successful. Employing a mountain stream at Vizille, $8\frac{3}{4}$ miles from Grenoble, as the initial source of the energy, he was enabled to convey through a very light wire a seven-horse power, representing when it arrived at the end of its rapid journey 62 per cent. of the force taken at the fountain head at Vizille. This power, so cheaply obtained, is moving in Grenoble several printing and other machines, lighting 110 Edison lamps, and generally holding out a brilliant prospect of what may be soon accomplished in other towns so happy as to be in the vicinity of a waterfall, or even of the sea, the tide being used as a generating power.

The railway from Portrush to the Giants' Causeway is 6 miles long, and the force to work it is generated by a waterfall in the river Bush, with an available head of 24 ft., the electric current being conveyed by an underground cable to the end of the tramway. The water-power passing through turbine water-wheels, which utilise the whole force of the fall, is said to amount to ninety horse. It is obvious that for a light train of tram-cars there is enough and to spare. The practicability of such a line is now a settled matter. The only question is whether it is likely to pay as a commercial venture. Considering that the initial power costs nothing and that coal in Ireland is dear, there are good hopes that a line certain to be freely used by tourists will satisfy the expectations of its projectors.

Taking, as the basis of their calculations, the expense of working a steam tramway engine at Portrush, it is claimed that while the old system cost on an average £8 4s. 9½d. for the engine per week, the electric cars can be run with the same number of passengers for nearly £2 6s. less.

The electricity generated at the waterfall is at once conveyed to the railway through an insulated wire. It is then carried along by the side of the tramway through a conducting rail, which is carried at some distance above the ground and supported on insulators. An arm, with a brush or pad at the end of it, stretches out from the train and keeps contact with this conductor, thus conveying the electricity to the machine which it has to work upon the car. In this way a sufficient and constant supply of force is kept up from the outside, and the car is not obliged to carry with it the ponderous accumulators with their stored supply.

To agriculture, electric transmission of power seems well adapted for effecting the various operations of the farm and fields from one centre. Sir William Siemens has worked such a system, in combination with electric lighting and horticulture, for some years, and he speaks with confidence of its economy, and the facility with which the work is accomplished in charge of untrained persons.

The application of transmitted electric energy to agricultural implements and machines of almost every description, is, indeed, a very simple matter. No gearing is necessary, a single insulated going and return wire serving to convey the power from the dynamo to an electro-motor attached directly to each machine. In this way the driving power for a threshing-machine, a chaff-cutter, a root-pulper, a corn-bruiser, and even for such field implements as the plough and the drill, can be brought from any distance with little or no loss of effect.

There are certain classes of agricultural machines which it will, perhaps, be more convenient to work by means of stored electricity. Two years ago the storage of electric energy in black boxes, and their power taken out of them, by Sir William Thomson, may have appeared visionary to many, but to those who could foresee the possibilities connected with the electrical storage of power these experiments of Sir William Thomson were of pre-eminent importance.

"The two latest employments of electricity, stored in Faure-Sellon-Volckmer accumulators, are in the boat *Electricity*, which many may have seen running at Kew, and the electric tricycle of Professors Ayrton and Perry. In the tricycle no work is done by the rider, but little black boxes, carried on the base-board, contain the stored electric energy, pretty much in the same way as a horse's body contains its breakfast of oats and hay, with the difference that with the accumulator it is the receptacle which has weight, so that neither in receiving its feed in the morning nor discharging its power during the day, does the accumulator gain or lose in its weight. By means of a tap, the rider can turn on more or less electricity, and go faster or slower."

The time, we imagine, is not very distant, when the ploughman will be seen riding on his plough with one or more days' store of electric energy under the seat, and the implement he steers turning over the soil with a speed, ease, and economy that immeasurably distances even the best performances of the steam-plough.

Professor Ayrton predicts a time when electric power will be supplied, as gas is now, to houses for lighting purposes; and when this has been accomplished, the same wires that convey the electricity for lighting will be employed to convey the power to work electro-motors to turn domestic machines.

It has been found impossible to supply by steam or gas-power a compact and practical engine to drive a sewing-machine, a small lathe, a fan, a rotary knife-grinder, a boot brush, or any of the thousand household machines which require but a small power. For such purposes, however, the little "Griscom" electro-motor is admirably adapted and is already extensively used.

The apparatus in question is, in fact, a cheap, compact, and effective household engine, consisting of a small electro-motor, which can be adapted to drive any sewing-machine, together with a battery in a box, containing a supply of electricity sufficient for several months' work. The motor is a tube of soft iron wrapped with insulated copper wire, with a segment left bare on either side. The ends are closed by brass plates, which are at the same time the bearings of a small "Siemen's" armature which revolves inside the tube. The current is brought to the commutator of the armature, *i.e.* the part where the ends of the wire are fixed, by two light springs bearing rollers, which revolve against the commutators. The current is brought to two binding posts in connection with the rollers. As soon as a current is set up the armature revolves with great speed (up to 5,000 evolutions per minute) and with much power. The name "double induction" is given to the apparatus by reason of the ingenious way in which the induced or secondary currents are utilised instead of acting as a brake. By a reversing attachment the motion of the motor can be reversed while running at full speed.

These motors are made from $\frac{1}{4}$ man-power to 1 horse-power. By combining a definite number of motors, any machine power required can be obtained.

A "Griscom" motor, weight $2\frac{1}{2}$ lbs., of about $\frac{1}{4}$ man-power, for driving small machines, costs about £3. A 1 man-power motor, weight 6 lbs., costs £7. A 1 horse-power motor, weight 40 lbs., costs £25.

The Electro-Dynamic Company, who are the manufacturers of the "Griscom," have perfected a bichromate battery, which is adapted specially to their motor. It consists of a six-cell bichromate cell in a strong locked box with a pedal, which, without any effort on the part of the operator, lowers the plates into the liquid, and at any desired depth, thus regulating the speed. A spiral spring lifts the plates out of the liquid, which emits no fume or smell, and the battery does not therefore waste when not working. The life of the battery depends on the charge, and can be indefinitely prolonged by renewing the chemicals and zincs.

A six-cell automatic battery, with carbon zincs complete, and spring and lowering attachment, costs £3 4s. A twelve-cell battery, for 1 man-power battery, complete in box, costs £9.

Large motors are most economically driven when they receive the current from a dynamo-machine.

Clarke's Patent Battery dispenses with dynamo-machines and accumulators, which need recharging, and enable the motor to be kept up by refilling the batteries with a simple chemical compound.

CHAPTER VII.

HORSE GEAR.

THE employment of horses for working threshing-machines and other barn or food-preparing machines is not now nearly so common as formerly, it being considered, on all but very small farms, that the work can be more economically performed by means of a small-power portable steam, hot-air, or gas-engine. When this is the case, the favourite method of transmitting power is through belting, or by means of a driving shaft, instead of toothed wheels.

Very expensive horse-wheels were formerly constructed of substantial and durable character, and fixed in an appropriate building. They are of two kinds, the overhead and the underfoot wheels. The diameter of them is often made equal to the entire diameter of the horse-walk, and toothed on its outer edge. The speed is at once got up by this means, but it is exceedingly irregular in its action, and is a dead pull for the horse, there being no intermediate parts to equalise the strain by their elasticity, which is necessary to animal labour. The manner of yoking horses when employed in this way is of considerable importance, as the horse is always exerting himself in a direction tangential to the circle of his walk; the animal, therefore, should draw by a swing-tree instead of a yoke, attached to a beam over head. In the case of one horse hanging back and leaving the others to do his work, an arrangement has been made which effectually prevents it. 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; by this means every horse is compelled to bear his fair share of the load.

None of these horse-wheels are ever now erected, a portable description having taken their place. The modern horse gears possess, owing to their being self-contained, portable, and easily fixed in any desired spot, merits which do not belong to the old-fashioned horse gears, with the large overhead first-motion wheels.

There is still a very considerable use of horse gears on English farms, as is evinced by the large trade done in them, as shown at exhibitions of agricultural machinery.

On all farms where steam-power is not at command, the farmer must fall back upon horse gear for operations of daily occurrence, such as preparing food. Nay, even where steam-power is used, we are convinced that horse gear, for certain operations, may be economically employed. For example, the pulping of roots should be a daily operation, as their virtue depends materially upon their freshness. It would be a costly business having to use steam for this purpose, one horse (or pony) an hour or two being sufficient.

In Fig. 23 is given an illustration of Crowley's Patent One-horse Gear, without cover to show the working parts. This horse gear was awarded a silver medal by the Royal Agricultural Society at Carlisle in 1880, where it was severely tested on the Dynamometer, and though only for one horse, stood the test of transmitting four-horse power. It is fitted with safety clutch for stopping the pole when the horse stops.

In this gear, the main wheel forms the frame, the bevel teeth of which face upwards. Under the rim are six supports which rest upon the arms, all of which are cast together and form one compact wheel and frame. From the centre boss of the wheel is fixed an upright shaft, upon which is placed a double bevel wheel and pinion, the large wheel of which acts upon and turns the bottom horizontal shaft, which runs in two bearings formed on the frame or arms of main wheel. Upon the upright stud or shaft rising from the centre is placed a horizontal carrier, upon which is fixed the draw-bar or pole to which the horse is attached. This carrier turns round upon the stud when propelled by the horse, and gives motion to the double wheel pinion on the centre stud by means of a shaft which has keyed upon it, at the outer end, a pinion which runs upon the main wheel, and a wheel at the other end, which acts direct upon the pinion of the double wheel, every wheel being so placed that the friction is taken off one wheel by the action of the others. It has a small intermediate without wheels; but having

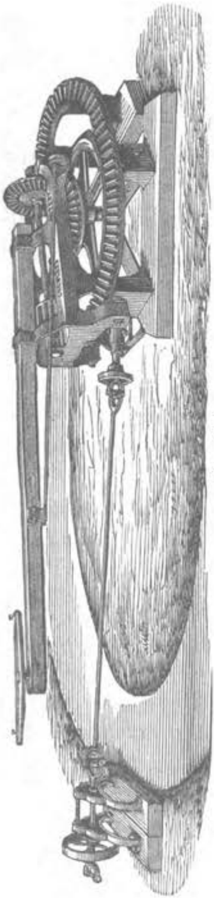


Fig. 23.

a short shaft fitted with shackle, joint, and one pulley, connected in the usual way to the gear with joints and pins. Its leading points are strength, easy working, and speed; one turn of the horse gives 37 revolutions, or at the rate of from 100 to 120 revolutions per minute. The price varies from £8 upwards according to horse-power.

Bamford's Improved Patent Safety Two-horse Gear, with spring racket, especially designed for preventing accidents to horses, is shown in Fig. 24. This, also, is a very complete, strong, and safe horse gear. The main driving-wheel is 44 ins. diameter, and is made without any openings or spokes, so that it is impossible for an animal to get its feet entangled in the gearing. The framework is most solidly constructed, and consists of two castings only, with four pillars, thus having great strength and durability. This gear makes 7 revolutions to 1 of the horse, and 43 revolutions with intermediate motion attached.

Endless-Chain Power.—Fig. 25 shows an improved horse-power of the kind, so extensively used throughout America on farms of moderate extent.

"The power of these machines and the amount of friction in running them may be ascertained by the rule for determining the power of the inclined plane, for the only difference between the endless chain and a common inclined plane is, that in one the plane is fixed and the body moves up its surface, and in the other the plane itself moves downward, and the weight or animal upon it remains stationary. The same principle applies in both cases.

"First, to ascertain the friction, let the platform be placed on a level with the horse upon it; then gradually raise the end until the weight of the horse will just

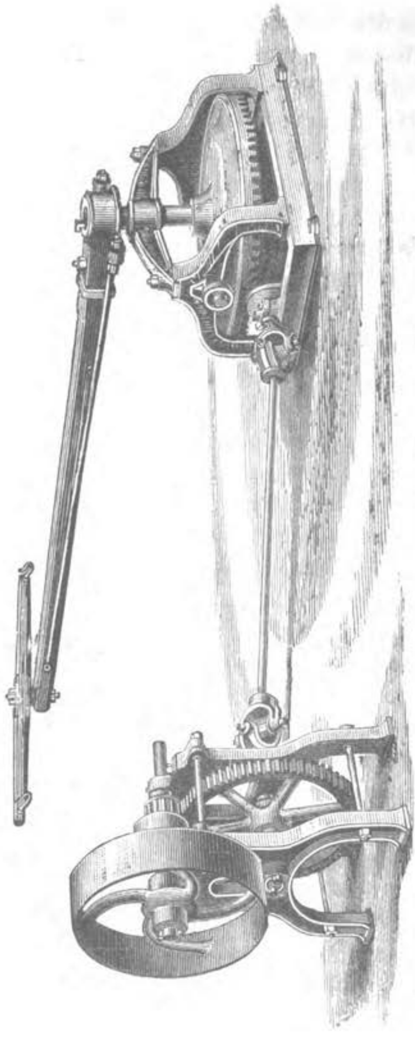


Fig. 24.

give it motion. This will show the precise amount of the friction; for if the end be elevated one-twentieth of its length, then the friction is one-twentieth the weight of the horse and platform.

"Secondly, to determine the power when the end is still further raised, measure the difference between the

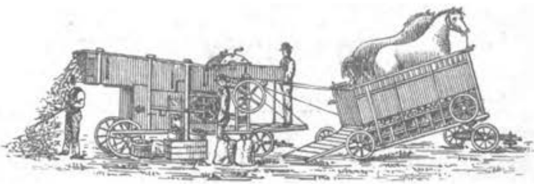


Fig. 25.

height thus given and the length of the platform. If, for instance, the height of the inclination is one-eighth of its length, and the horse is found to weigh 800 pounds, then the power is 100 pounds, or one-eighth the weight of the horse."

The tread power is successfully applied to churning and other light operations in which the weight of a sheep or a dog suffices to drive the machine. A sheep is more convenient than a dog for the purpose, as it is heavier, more quiet, less averse to the labour, and when the task is done, it is turned into the yard or pasture where it is readily found next time.

CHAPTER VIII.

DYNAMOMETER, OR DRAUGHT GAUGE.

THIS is a simple instrument for testing the draught of ploughs or other implements and machines.

As an example of the utility of the dynamometer, the farmer may wish to choose between two ploughs which, so far as the eye tells, may do their work equally well; but this instrument, when applied, may show that the team must exert a force of 3½ cwt. to draw one of them through the soil, while the resistance of the other is only 3 cwt. If other things were equal he would therefore select the one of easiest draught, and save the labour of his horses. The same advantage may be derived in the selection of harrows, cultivators, chaff-cutters, threshing-machines, and all other machines worked by men or by horses.

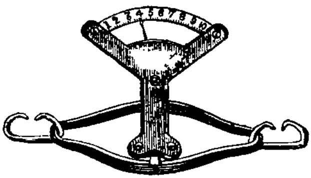


Fig. 26.

It is found that a pair of ordinary farm horses, walking at the rate of 2½ miles an hour, will work an implement, the resistance of which is about 3 cwt.

Fig. 26 is an engraving of Howard's Dynamometer or Draught Gauge, which will be found exceedingly useful for the purposes above mentioned. The end of this instrument is hooked to the implement, the other to the whippletree; and, as the horses draw, the spring is collapsed, and the draught is indicated on the dial. The price of the instrument complete is £3 5s.

The Self-recording Dynamometer, shown in Fig. 27,

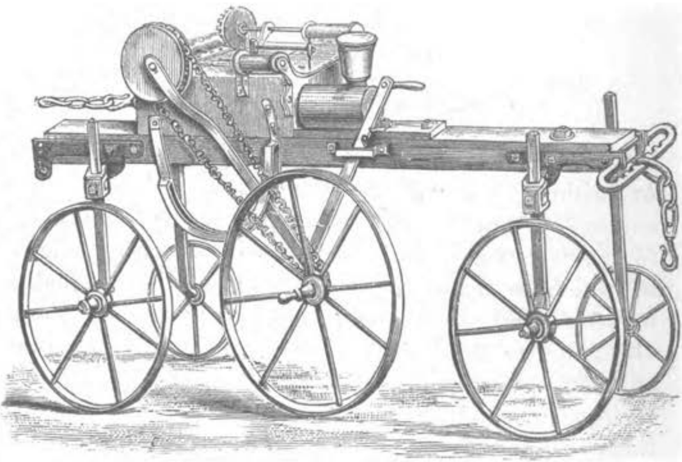


Fig. 27.

has also been designed by J. & F. Howard for the purpose of ascertaining the draught of ploughs, mowers, reapers, and other implements or machines. The self-registering apparatus gives the exact draught, and also indicates the oscillations which have taken place. This instrument is of special value to agricultural societies requiring to ascertain with great accuracy the draught of various implements or machines.

CHAPTER IX.

THRESHING-MACHINES.

THRESHING-MACHINES are classified as "double blast" or finishing, and "single blast" or non-finishing machines. There is perhaps no single machine designed to carry out any series of operations or processes, in which so many conditions and circumstances are involved, and have to be fully considered and provided for, as the finishing threshing-machine. Not only does every country produce even the same grain with straw of different lengths, with varying proportions of grain to straw, of grain to ear, of beard and chaff to ear, and with different proportions of weeds and seeds in the crop; but the circumstances of dry and wet seasons, and of heat or cold, affect the conditions under which the threshing, cleaning, and separation of the grain and seed can be effected. In England, threshing is performed at almost all times of the year; and the crop is consequently in different states of dryness, depending upon the season and weather when it is threshed, the time it has remained in stack, the part of the country in which it is grown, the situation in which the stack has been placed, and, if threshed directly after harvest, the amount of rain and of sunshine during harvest. In most foreign countries it is threshed when harvested, and is consequently very often extremely dry and very brittle; while the quantity of weeds grown and collected with the crop is sometimes more than the crop itself.

These facts give a faint idea of the chief causes of the manifold difficulties and conditions involved in producing successful threshing-machines; these will, however, be better appreciated when the details by which these difficulties are overcome are described.

The primary operations performed in threshing are—

1. Separation of the grain from the ear and straw.

2. Separation of the grain from short broken straw and pieces of broken ear (cavings and chobs), and from the chaff.

3. Separation of the grain from dirt and seeds.

4. Separation of the grain into different qualities.

In most countries these involve—

1. Threshing the whole crop, with greater or less length of straw, and passing it between a fixed or a rapidly revolving ribbed surface.

2. Shaking the straw, to remove any grain, seeds, chobs, and chaff that may be carried by it.

3. Passing the whole of the products of threshing, except the straw, over rapidly reciprocating riddles and sieves, in presence of the blast from one or more fans.

4. Passing the grain through a cylinder provided with revolving beaters or arms, to remove any firmly adhering chaff, awns, or beard, followed by final sifting on secondary sieves.

5. Passing the grain through a revolving screen.

The principle and operation of the modern threshing-machine is very clearly shown in the longitudinal section (Fig. 28) of one of Marshall's machines.

One of the chief differences between the early and

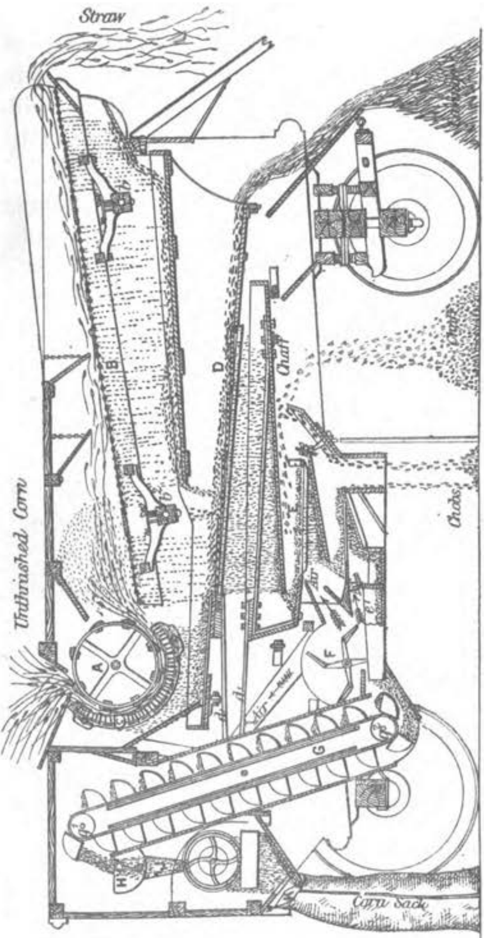


Fig. 28.

A.	Drum.	F.	Fan.	e.	Lower sieve.	J.	Rotary screen.
B.	Straw-shaker.	b^1. b^2.	Crank-shafts.	e^1.	Corn-shoot.	K.	Corn-spout.
C.	Shog-board.			G.	Elevators.	g^1. g^2.	Pulleys.
D.	Caving-riddle.	d. d^1.	Connecting rods.	H.	Smutter.		
E.	Dresser.			I.	Second blast.	j.	Spout leading to screen.

modern threshing-machine is in the construction of the drum and the speed at which it works. In the early machines, the cylinders, or drums as they are called, which carry the beaters, moved at a velocity of about 250 revolutions per minute: in the present machines the drum makes quite a thousand revolutions per minute.

In the old threshing-machine the corn was fed in between two fluted metal rollers which retarded the motion of the sheaf whilst the beaters on the circumference of the drum were knocking out the grain. In the modern machine, the rollers are altogether discarded. There is an iron concave grating, made to agree with the sweep of the beaters, from which it stands about $\frac{1}{4}$ of an inch. The sheaves are fed loosely into the space between the grating, and the quick revolving drum and the scrubbing action are sufficient to free the grain from the straw.

The straw-shaker separates the grain from it most effectually, and can also be made to send forth the straw straight and unbroken, which is an important matter when it has to be sent to market instead of being consumed on the farm, and even in the latter case the "shakers" save waste.

The shakers receive their motion from one or from two cranks. The width of the shakers is usually about equal to the length of the drum, their length being about double that of the drum. A considerable stroke is necessary for a shaker crank, in order that the shaking of the straw may be sufficiently violent to effect the complete separation of the grain from the straw. An average throw of the crank is 4·25 in. with 345 strokes per minute, or 0·0203 of drum surface speed.

After passing the first dressing apparatus in which the cavings and short straws, the chaff, the chobs, and the small seeds of weeds, sand, &c., are separated, the corn is carried to the top of the machine by a cup or blast elevator, whence, after passing through an awning and smutting apparatus, it comes down into a second dressing apparatus, consisting of at times a rotary screen, at others of a series of riddles or sieves, through which the corn percolates while being acted upon by a blast which carries away the beards, chaff, smutt, &c. A separate spout conveys refuse of all kinds to the ground. No good grain can escape, and the screen separates it into three qualites, the size of the corn in each being determined by the adjustment of the wires.

In the most improved machines, a single high-speed fan or blower is attached to the drum-shaft, from which the necessary blasts of air are conducted through separate channels and brought into contact with the chaff and corn at different points. The pressure of these several blasts of air is regulated by simple valves under the control of the attendant, and can be modified to suit any kind of grain under operation. By thus dispensing with a second fan, the necessary number of spindles, bearings, pulleys, and driving belts, as well as the wear and tear, and bulk and weight, of the machine, are all reduced to a minimum.

The "single blast" machine has no second dresser, and does not finish for market. It remains much the same as it was many years ago; but is now only in favour with farmers who thresh for the granary, or before their corn is in a fit state for marketing.

Messrs. R. Garrett and Son, of Leiston Works, Leiston, have recently produced a novelty in their rolled steel reversible drum-beaters. The primary object of this invention is the provision with every threshing-machine of the equivalent of a new set of drum-beaters, as these, when worn on one side or face, can be reversed. Another feature is as follows: The drums of threshing-machines are commonly composed of eight ribbed beaters in which the ribs run upon the surface of the different beaters alternately from right to left, and *vice versâ*. In the new beaters the ribs run on one side or face from left to right, and on the other side from right to left, so that with one set of rolls the needful beaters for a drum can be produced. It is, further, a matter of considerable convenience to the

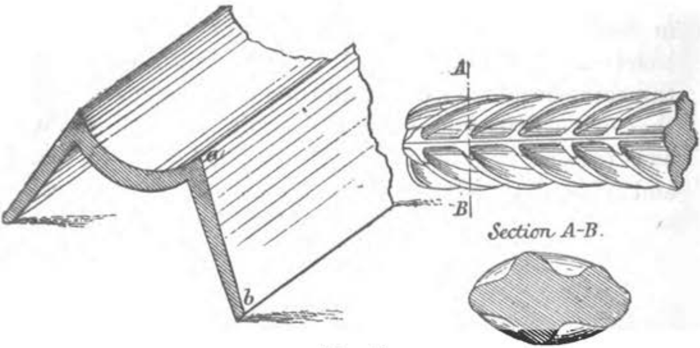


Fig. 29.

owners of threshing-machines to have beaters which are thoroughly interchangeable, so that a smaller stock of costly wearing parts is necessary in order to be provided against occasional accidents. In carrying the invention into effect, the principal difficulty to be contended with was the provision of a suitable bed for the reversible beaters in the surface of the drum. To this end continuous rolled steel chairs are employed of an inverted ⊔ section, hollowed on the top surface to receive the beater, from which it is parted by means of a strip of papier-mache, and having the legs set at a suitable angle (of about 135 deg.) to the radius of the drum to project the corn against the concave surrounding the drum, where it is further operated on by the ribs of the beaters proper. A principal feature in the construction of the combination of the chair and beater is the depth of threshing surface, A B, which permits of a slower speed of drum than heretofore without incurring the danger of "winding" the straw or failing to thrash clean. Fig. 29 shows the arrangement perfectly.

For the prevention of accidents to those employed in feeding the machine, a recent Act of Parliament enacts that the drum and feeding-mouth of every threshing-machine shall at all time during the working thereof be kept sufficiently and securely fenced, so far as is reasonably practicable and consistent with the due and efficient working thereof. There are now several patent safety drum-guards in use, but they all depend on one of two principles. "Some makers think with R. Garrett and Sons that there is no danger of accident to the feeder so long as he is in his box; and it is only when he is out of it that there is any possibility of his falling into the drum. Their guard (Fig. 30) consists simply of a cover, which always remains closed over the mouth of the machine until the feeder gets into his place, when his weight depresses the bottom of the box

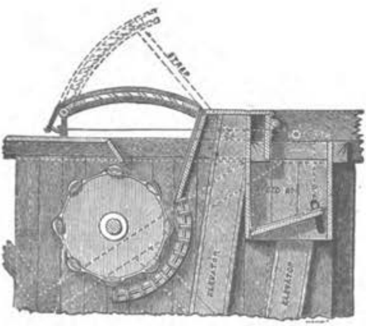


Fig. 30.

a little, giving movement to suitable levers, and opening the mouth of the machine. Other makers arrange matters in such a way that if any undue pressure comes, either upon the feeding-board, or a curved hood which covers half the drum opening, the latter is instantly closed by a self-acting shutter or flap." (*Pidgeon.*)

The latter principle is illustrated in Ransome's Safety

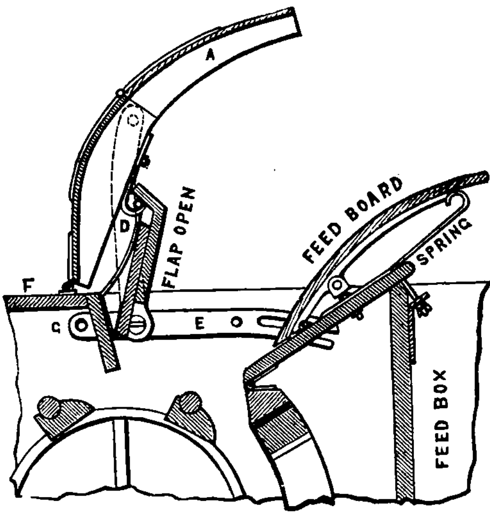


Fig. 31.

Drum Guard (Fig. 31). It is so constructed that it is almost impossible for any one to fall into the drum of the machine, as will be seen by reference to the drawings. A self-acting flap, or shutter, which, when down, completely closes the mouth of the drum, is so arranged that when open it does not interfere with feeding the machine, but will drop instantly and close the drum if any one falls either on to the hood A or feed-board B. Sweepings can be swept into the drum as usual, and the guard can be easily applied to old machines at a small extra cost.

Several makers of threshing-machines have sought to combine with the drum-guards a self-feeding apparatus. The first of these was brought out by Wilde, of Reading, in 1871, and has since been adopted by Clayton and Shuttleworth, and other makers. It consists, in effect, of a small straw-shaker, which delivers into the drum mouth, and is fed by an attendant, who himself stands in a place of safety. Above the shaker hangs a spiked rake, under whose teeth nothing thicker than a layer of grain can possibly pass.

Marshall's Feeder consists of a spiked barrel fed from an inclined board. Beneath the latter three saw-toothed discs revolve, and the board itself is suspended by springs in such a manner that the weight of a sheaf depresses it sufficiently to allow the discs to protrude and cut the band. The loosened sheaf is then carried forward to the spiked barrel, until it reaches a line of oscillating forks, by which it is spread out evenly just before entering the concave.

Ruston and Proctor's Self-acting Feeder consists of a box, with an inclined feeding-table arranged in it, placed over the mouth of the drum and forming a large hopper into which the corn is thrown. At the farther end of this table there is a revolving hexagonal drum, provided with obtuse teeth which pick up the corn and carry it forward to the threshing-drum as fast as it can be supplied, whilst a number of vibrating tines arranged above split up the sheaves and effect an even distribution across the whole width. The feeding-table is supported by a self-acting spring with disengaging gear, which instantly stops the motion of the feeder in case any person falls or steps into it, and prevents any injury occurring.

Self-acting feeders have not yet been very generally adopted; but ultimately no doubt they will. They secure a full and uniform supply of corn to the machine, save labour in hand-feeding, and dispense with drum guards.

The following detailed description of Ransome's threshing-machine is from a paper read before the Institution of Mechanical Engineers by Mr. W. W Beaumont, in 1881.

This machine, of the size having a 4 ft. 6 in. drum, is illustrated by Figs. 32 and 33. This is only one of many different sizes and arrangements of machines made by this firm, according to the practice of all makers to suit the requirements of all countries. The arrangement and the purposes of the parts will be best understood by following the straw, &c., through the machine.

Fig. 32 is a longitudinal sectional elevation.

Fig. 33 is a transverse section of the machine at the hinder end, taken through a line a little within the end framing and looking from behind.

The man feeding stands in the feeding-box A^1, Fig. 32, and the sheaves of corn, after the binders have been cut, or the corn of whatever sort in a loose form, is handed to him by other workman standing on the top or platform of the machine. The feeder then passes it into the drum mouth A, with as much regularity as possible, over the feeding-board A^2, it is then caught by the drum B, and rapidly carried between it and the concave B^1. The grain is knocked and to some extent rubbed out of the ear, and the ear more or less broken and separated from the straw, as it passes between the

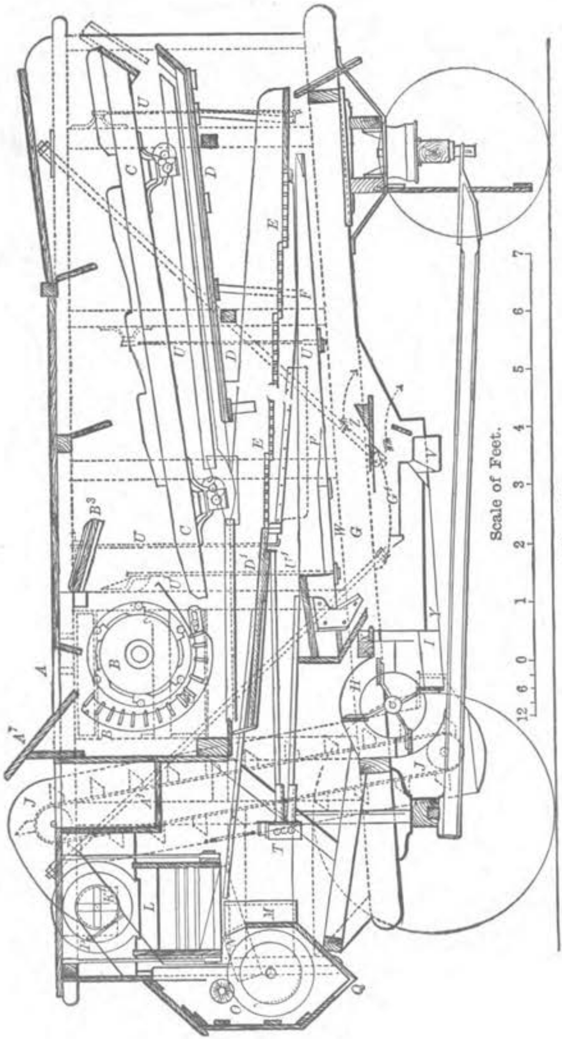


Fig. 32.

drum and concave; most of the grain falling through

the concave grating and the rest passing with the straw on to the shakers C; the straw carrying with it some grain and a good deal of the chobs and cavings. All these are shaken from the straw on the shakers, and pass through on to and down the oscillating-board D, whence they pass on to the upper part of the riddle surface E. The greater part of the grain, seeds, chaff,

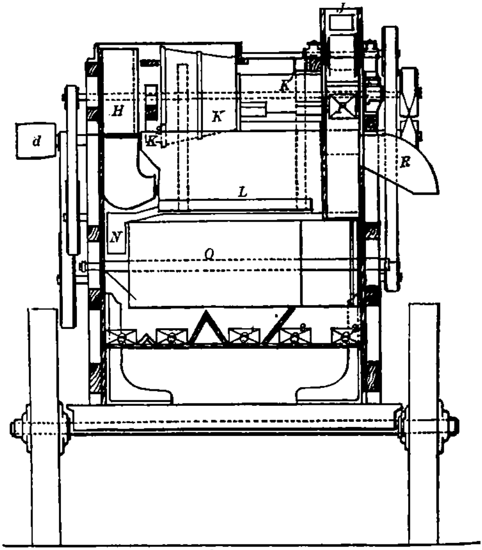


Fig. 33.

&c., which fall through the concave, passes on to the oscillating-board D¹, and thence also on to the riddle surface. The straw, from which all grain, &c., has now been separated, passes upwards and falls over the upper end of the shakers; while the grain, seeds, chaff, and chobs pass down to the bottom of the oscillating-board F, most of the small seeds and dirt being separated in the passage thereto by falling through the perforated plate or sieve over the spout W, which carries them away. The remainder of the material, including all the grain, chaff, chobs, and some seeds, passes to the end of the board F and falls down the inclined board X on to the upper sieve G. Through this sieve most of the grain falls to the bottom of the shoe at Y, a blast of air from the fan H assisting in the sifting by blowing the chaff from the sieve, especially that which tends to fall off its end out of the shoe in the direction of the upper arrow. Some of the small pieces of imperfectly threshed ears and grain with adhering chaff are also blown in that direction; but owing to their weight they are not carried beyond the stop bar on the board Z. From the board Z these chobs pass down the inclined plane to the second and lower sieve G^1; the heavier chobs from the end of the upper sieve also fall down to G^1, some grain falling with them. On G^2 the sifting is repeated, the grain falling to the bottom of the shoe, and the whole of the chobs falling into the chob-spout V, whence they drop into baskets and are again passed through the drum for a second threshing. There now remain only the grain and some of the larger seeds to be dealt with, the grain having received its first dressing.

For the second dressing and screening the grain passes through the spout I to the bottom of the elevator-box, and is thence taken by the cups of the elevator J to the top of the machine, and delivered into the cylindrical part K^1 (Figs. 32 and 33) of the awner. When, however, the grain is remarkably uniform in quality, and the crop very clean as regards freedom from weeds, and when it is intended to dress the corn (if that is further necessary) in a dressing-machine, the grain is allowed to pass at once out of the machine from the elevator spout to the sack spouts Q; for which purpose a slide shown in Fig. 32, at P, is provided. The same remark applies when beans are threshed. From K^1 (Fig. 33) the grain is passed by the revolving arms therein through the awner K, in which any firmly adhering chaff is rubbed off the grain and the smut balls broken, and thence it falls through the spout K^2. From K^2 the grain drops on to the upper sieve in the second jog-shoe L, Fig. 33, and is successively sifted by the several sieves shown in cross section in Fig. 32, the larger seeds and any stones being rejected and passed down the spout M, while the grain goes through the spout N into the rotary screen O. At H (Fig. 33) is a second fan from which a blast is directed between the sieves in the jog-shoe L; and by this blast all dust (some of which results from the broken smut balls) and the chaff or beard which has been rubbed off in the awner is blown off through the dust spout R (Fig. 33). In the screen O (Fig. 33) the smallest corn drops at once through the spouts Q Q, and forms the third quality. The grain next in size drops through the spouts Q^2 Q^2.

To provide room for the men working on the top of the machine in attendance upon the feeder, the platform is increased in width by boards not shown in the diagrams, but which are hinged to the top edges of the frame and supported at their extremities by struts resting on the bottom members of the frame.

The drum B in this machine (Fig. 32) has width of 4 ft. 6 in., and consists of six beaters mounted upon iron-faced beater-bars, which are fastened by hook bolts to three-flanged plate drumheads, and to two intermediate wrought-iron rings. The plate drumheads are fastened to cast-iron bosses keyed on to the drum-spindle, which revolves in long bearings fixed to a cast-iron bearing-plate bolted to the two vertical frame pieces. The beaters are themselves long screws made by twisting rolled bars. After these are twisted and straightened, grooves are cut in them, at the necessary distances apart, to receive the hook bolts by which they are held on the drum.

The concave B^1 (Fig. 32) is made in two parts connected by a long transverse pin or bolt a little below the sectional length of the concave. It consists of two main end pieces of wrought iron, and a number of intermediate similar shaped ribs, forming a support to the ribs running transverse to the machine, which are seen in section in Fig. 32. These latter ribs are perforated near their upper edges, and receive curved wires generally about $\frac{5}{16}$ in. in diameter.

A coarse strong grating is thus formed, which is adjustable as to distance from the drum at three points, namely, in the upper part, a little below the middle, and at the forward end of the bottom. The long bolts on which the segments rest pass through the outside of the machine and are there held by three sets of adjusting gear, two being below the drum-spindle and one above, and all attached to iron bearing-plates. The lower part of the concave is made somewhat more open than the upper part. The distance at which the concave is set from the drum is always greater at the top than at the centre, and at the bottom or forward part it is least, the actual distance varying with the nature and condition of the grain to be threshed. For wheat, oats, and barley, in average condition and quantity of straw, it is usually set at $\frac{3}{8}$ in. from the drum-beaters at the bottom, from $\frac{5}{8}$ to $\frac{3}{4}$ in. at the middle, and about $1\frac{1}{8}$ in. at the top. For very damp or very dry corn it is, however, set wider or closer respectively, as experience dictates. Sight holes at the side of the machine are provided, through which the distance between the bottom and middle of the concave and the drum may be seen while making adjustments, the distance at the top being seen from the drum mouth.

The advantages of the screw or twisted drum-beater are that, besides being a good thresher, it can be turned as wear takes place, and from two to four new faces presented according to the care taken by the attendants. Moreover, as all feeders habitually feed more towards the centre and one end of the drum, rather than uniformly throughout the whole length, the beaters can be changed end for end with advantage. As the drum runs at a very high velocity, it is necessary that it should be most carefully balanced, and that every part should be of good material and firmly connected.

It has been mentioned that the grain, as the corn or crop passes between the drum and concave, is knocked and perhaps to some extent rubbed out of the ear; but it will be seen from the construction of these parts and the fact that the velocity of the periphery of the drum is 6,047 ft., or considerably over a mile per minute, that the rubbing can only be effected by the straw as it is whisked from drum-mouth to shakers.

In leaving the drum and the directing plate, which is curved upwards a short distance from the concave, the straw flies upwards; its fall upon the ends of the shakers is determined by the inclined board B (Fig. 32), which is adjustable as to inclination. The straw is checked from too rapid ascent of the shakers by two swinging shutters placed across the whole width of the machine, as shown in Fig. 32. The shakers consist of four sets of reciprocating wood-frames or boxes, the upper parts of which are filled in with small transverse strips of wood, placed at a short distance apart, so as to form a grating. These sections are mounted upon brackets carrying bearings, and worked by two sets of cranks, S S (Fig. 32). The cranks are set at equidistant angles of 90°. Each shaker-box or section thus receives a similar compound motion, by which the straw is thoroughly shaken and carried forward, while the shaking is increased by a deeply-notched longitudinal piece placed along the middle of the top of each shaker-frame.

The board D (Fig. 32), which receives all that is shaken from the straw, and the board D^1, which receives all the grain, &c., which has dropped through the concave, receive their motion from the crank T, which also gives motion to the wood riddle E. These boards and the riddle E are connected, so that their motions are simultaneous. The rod by which they are connected with the crank T is fixed under the board D^1, and is thinned or flattened near the point of its fixture; being thus made flexible it needs no joint. The riddle surface, which is usually constructed of mahogany or walnut, is grooved in the direction of the length of the machine, the grooves being of 1 in. pitch, and the holes of different sizes from $\frac{1}{8}$ in. to $\frac{7}{8}$ in., the smallest sizes are for such grain as wheat and rye. These parts are suspended by hangers U U, which are firmly fixed at either end and consist of thin strips, usually of tough ash. The board F and the other parts of the lower shoe are suspended by similar hangers (Fig. 32). The shoe also receives its motion from crank T, and is connected therewith by a flexible rod as shown in Fig. 32.

When threshing oats the seed-sieve at W is taken out and a blank plate put into its place, but the seed-sieve is left in for threshing wheat and barley. The sieves G and G^1 vary in mesh from $\frac{1}{4}$ in. to $\frac{1}{8}$ in. according to the grain being threshed. The strength of the blast through and past these sieves is regulated by a slide shown near I (Fig. 32). This blast must be regulated with great care, so that all the grain, including the light grain and chobs, may drop within the bar Z, while the chaff from the upper sieve must be carried beyond that bar. The construction of the fan H is sufficiently shown in the section (Fig. 32).

The elevator J consists of a leather belt, provided with a number of tin-plate cups of the transverse section, indicated in Fig. 32; the speed of the belt is made sufficient to elevate the grain from a full crop. The awner K is provided with knives and beaters, which may be used in part and separately, or all together, at the discretion of the attendants of the machine, and according to the character and condition of the grain being dressed.

If the grain is smutty or brittle, it is usually not passed through the awner, but delivered direct to the second dressing shoe L, the sieves in which vary according to the grain to be dressed, being, for instance, of $\frac{1}{8}$ inch, $\frac{1}{4}$ inch, or $\frac{3}{16}$ in. mesh. Some sieves are made of perforated iron or zinc, others are of woven wire, others again are made with parallel wires. For barley, which is difficult to awn, and for wheat to which there is much firmly adhering chaff or white coat, the whole of the beaters are sometimes used in the awner instead of the knives. The awns and chaff thus removed have to be blown from the sieves in the second dressing shoe L by the blast from the fan H^1, and the force of this blast must be carefully regulated so that no grain is carried away. The screen o is a rotary wire screen, the wires being adjustable as to pitch to suit the grain to be screened. Near the front road wheels is a board, hinged at the upper part and lowered so as to assume a vertical position when threshing, to prevent a mixture of the chaff with the cavings.

As already stated, almost the whole of these details are subject to modification to meet the requirements of different countries and practices; and the relative dimensions are also subject to large modifications. In Australia, for instance, where the corn is generally cut off by the ear, the shakers are not needed, while all the riddling surfaces and the parts constituting the dressing apparatus must be very large.

Messrs. Ransome and Co. have introduced a straw-bruising apparatus for attaching to their threshing-machine in hot climates, where straw is unfit for the food of live stock until it has been crushed in some way or other. The straw as it comes from the shakers falls upon a roller furnished with knives, which cut it into rather long chaff. This chaff is fed into a concave, where it is crushed by a second roller armed with blunt pegs, and whence it finally issues thoroughly bruised and in a fit condition for food.

Clayton and Shuttleworth's Finishing Threshing-machine, Fig. 34, is fitted with their patent safety feed-board for feeding by hand, but Wilder's patent self-feeding apparatus can be attached to any machine when required. The drawing is for a 4 ft. small machine with cup elevators.

The straw-shakers in this machine are worked by a single crank shaft, and are very efficient, as the

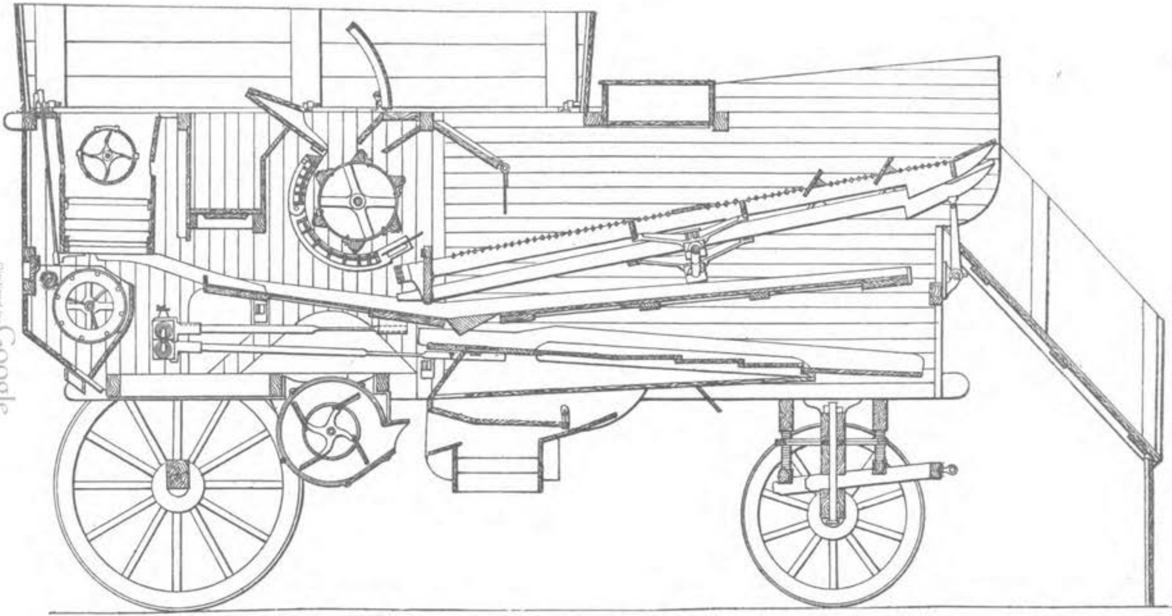


Fig. 34.

straw is alternately tossed up vertically and moved forward horizontally, which is the best motion for separating the grain and chaff from it. If desired, however, double crank shakers are supplied without extra charge. For the neighbourhood of large towns, where the straw is sent to market, the shakers are made to deliver it in as straight condition as possible.

The riddles and vibrating boards are hung on Coulson's patent spring hangers, which work without friction and require no lubrication. These parts being balanced and moving in opposite directions, the rest of the machinery is not affected by their vibration.

In the first dressing apparatus four separations are made, namely:—

Cavings and short straw.
Chaff.
Spoutings, such as sticks, stones, &c.
Small seeds of weeds, sand, &c.

The corn is thence lifted to the top of the machine by the cup elevator, consisting of an endless strap fitted with cups, which carry the corn up a spout and deliver it at the top; or in some machines this is effected by the patent blast elevator, which is made adjustable in speed and diameter and has three varieties of interchangeable plates for rubbing off the awns or beards of barley.

From the top of the elevator the corn falls into a separate barley awner and smutter, which consists of a shaft studded with steel knives and adjustable beaters, revolving in a cylindrical iron casing. It is so arranged that, at the option of the attendant, the corn can be operated on by the awner only, or by the awner and smutter; or it can avoid the awning and smutting process altogether.

The corn passes from the elevator or awner just described into a second dressing apparatus, consisting of a series of riddles through which the corn percolates while being acted on by a blast for carrying away the beards, chaff, smut, &c., rubbed off in the awning process. A separate spout conveys the refuse into a sack. Any good corn escaping the riddles, however, is carried back to the first dressing apparatus, so that no waste can take place.

On dropping through the last riddle, the corn enters the patent adjustable rotary screen, by which it is sorted into three qualities.

The machine is capable of threshing all kinds of corn and dressing and finishing it for market at a single operation. It can be arranged, however, to work as a "double blast" by passing the corn direct into sacks instead of through the rotary screen; or as a "single blast" by also removing the riddles from the second dressing apparatus and putting the small blower out of action.

Fig. 35 represents Howard's new patent "trusser," attached to a threshing-machine, by which the threshed straw is caught when leaving the machine, securely tied in bundles with stout twine, and thrown on the ground at the back of the machine, ready to be forked on to a cart or stack. The machine, which occupies very little additional space, is attached to the end of the threshing-machine. As the straw leaves the mill it falls between two revolving canvas aprons, and is carried down to the binding-table in a condition ready for tying. It is delivered in a loose form, but is caught and packed tight by a series of reciprocating points, till the required size of bundle is obtained, when the binding gear is set in operation. A feature of the machine is that it can be set so as to make the bundles various sizes; and as soon as the size that it is set to make is attained and packed, the pressure moves a lever, which brings the binding part of the

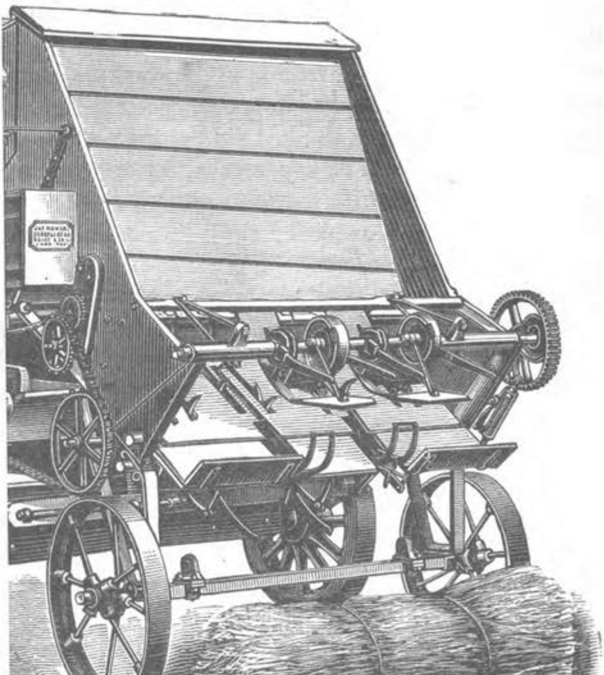


Fig. 35.

machinery into action. The arms or needles that have the string threaded through them are bound round the bundle, across the knotting-hooks, the string is gripped, and the knotters perform their work, the knives cross the path of the twine and sever it, and at the same time the levers on which the knives are secured pull off the loop-knots from the knotting-hooks, and eject the bundle to the ground. The needles then fall back to their normal position and await further operations. The whole operation is done instantaneously. Two strings are passed round each bundle at a distance of 15 inches apart, and the bundles are far more shapely, more tightly packed, and more easily handled than bundles made by hand. The machine is said to do the work of six men.

Where it is desired to cut up the straw at the time of threshing, Messrs. Clayton and Shuttleworth supply a large chaff-cutter for attaching to the tail of the machine, and it not only cuts up the straw but sifts and bags the chaff as fast as the straw can be delivered from the thresher. This apparatus will be found more fully described under the head of Chaff-cutters.

In Nalder's Threshing-machine, the shakers, shog-board, and large riddle, are all driven from one crank placed centrally between the shakers, the shaker-boxes themselves being made to act as connecting-rods for driving the shoes. This arrangement dispenses with a great number of bearings, pulleys, and one belt.

Foden's Double-exhaust Finishing Machine was awarded a silver medal by the Royal Agricultural Society, at the York meeting in July, 1883. The principal improvement claimed in this machine is the introduction of an exhaust fan in the place of first and second blast fans, second riddle-box and riddles, and which not only does the work of both, but also acts as a chaff-cleaner and lifter, thus saving the driving power employed on the first and second fans, straps, time in oiling, and cost in repairs, &c. The exhaust fan makes a perfect sample of smut wheat, and will take all the light from any other grain perfectly.

The early threshing-machines were nearly all driven by horse-power, a few by water; now steam power is most generally employed. It seems to be pretty well agreed that, with the present price of horses, it will not do to thresh a large farm by horse-power.

For very small holdings, the "Tiny" threshing-

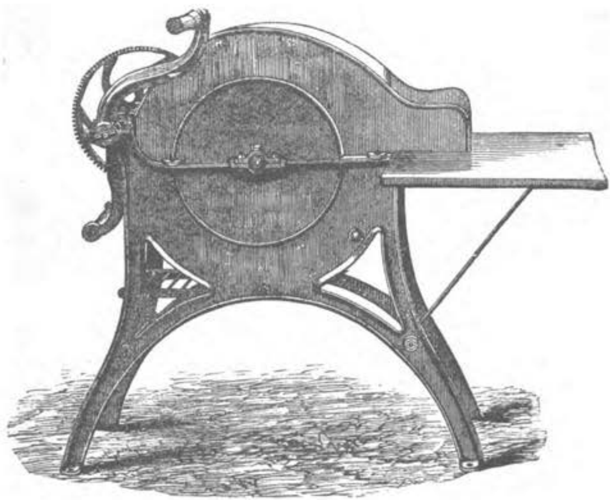


Fig. 36.

machine, Fig. 36, manufactured by Murray, of Banff, is extensively used. It is made in several sizes, adapted for hand, pony, or horse-power, and will thresh from 10 to 24 bush. of grain per hour. The prices vary, according to size, from £6 10s. to £37, complete.

A 4-horse threshing-machine will thresh from 20 to 30 bush. of wheat per hour, and from 40 to 50 bush.

of oats or barley, according to the strawiness and yield of the crop.

A steam thresher of 6 to 8 horse-power will thresh from 60 to 80 bush. of wheat per hour; or from 600 to 800 bush. in a day of 10 hours; and of oats or barley a third or even a half more.

The cost of a steam threshing and finishing-machine, say of 6-horse power, is about £135. This price will include a safety drum-guard; but the cost of fitting a self-feeding apparatus would be extra, as would also straw elevator, straw bruiser, or chaff-cutting, sifting, and bagging apparatus.

CHAPTER X.

CORN-DRESSING MACHINES.

WHERE the threshing-machine is a non-finishing one, separate corn-dressers of various kinds for hand-power will be required in order to properly prepare grain and seeds for market. The difference in price between a well-dressed and an ill-dressed sample of corn or seed is so great, that it pays the farmer to obtain the very best machines for this purpose, on even a moderate sized farm.

The most necessary of these machines is the winnowing-machine, for separating the chaff, light corn, small seeds, and dirt, from the good grain. In the ordinary winnower, a fan blast acts in conjunction with riddles, for the cleaning and separation of grain; but in some of the more recent machines, the blast is replaced by an exhaust fan.

The principle upon which the ordinary improved winnowing-machines act is this. A strong current of air is driven by the fan up an inclined tunnel, above which is a hopper, having a sluice gate, through which the corn is allowed to pass in any given quantity on to the riddles and sieves, which are made to oscillate. As the corn passes from the hopper into this shaking riddle, it is at once acted upon by the fan, and the lighter chaff is blown off; the remainder passes through the riddles into the sieves below, through which the good grain passes, while the light corn and the small seeds are blown past the sieve and fall into their proper channels.

Hornsby's Corn-dressing Machine (Fig. 37) presents several improvements on the above. It is fitted with a spiked roller, working through a grating so arranged as to form a hopper, and is easily adjusted to suit corn,

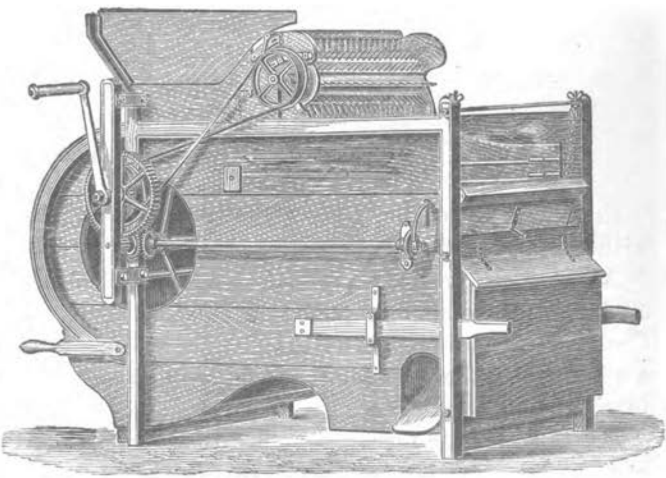


Fig. 37.

either in rough chaff or any other state. It is also fitted with a double shaking screen at the bottom, which more effectually cleans the corn from all kinds of small seeds than a fixed one.

These machines are sent out fitted to dress wheat, barley, oats, rye, tares, beans, and peas. They can also be used for blowing dust or smut from the grain, and are readily adapted for dressing seeds.

Boby's celebrated Corn Screens have recently received a further improvement by suspending the screening surface upon wood spring suspenders, thus doing away with the principal and most costly wearing parts, and reducing the power required to turn them to a minimum.

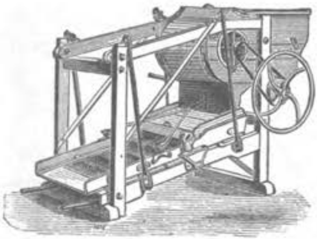


Fig. 38.

Any number of wire beds of different gauges can now be had with the same machine, and so arranged that they can be removed and replaced with the same facility that riddles are changed in a winnowing or dressing-machine. These screens are fitted with blower, as in Fig. 38; or the screen may be had without the blower.

At the York meeting, 1883, the Royal Agricultural Society awarded a silver medal to Messrs. Shield and Crockett, for an ingeniously simple corn screen. It is a wire screen, the wire being wound in one long spiral in such a way that the form of the cylinder produced is traversed by one furrow, which extends from end to end. The screen heads are cast iron, with heavy rims projecting considerably beyond the bosses, which fit loosely upon the shaft. They are thus allowed to "wobble" on the shaft, with the result that the wires of the screen are always closer together at the bottom than at the top. No brush or any device is required to clean the screen, as any grain which may fix itself in the lower part of the screen falls again freely within it when that part of the screen in its revolution reaches the top. The screen is thus self-cleansing, and being constructed in a spiral or screw form, the corn, &c., is conveyed out without the aid of any sheet-iron, worm, or other propelling device, so that the whole of the interior is screening surface. The machine is not only simple, but works efficiently in every way.

Fig. 39 shows the screen complete in frame. It represents the screen when closed for dressing seeds, &c., and being of simple construction it is readily

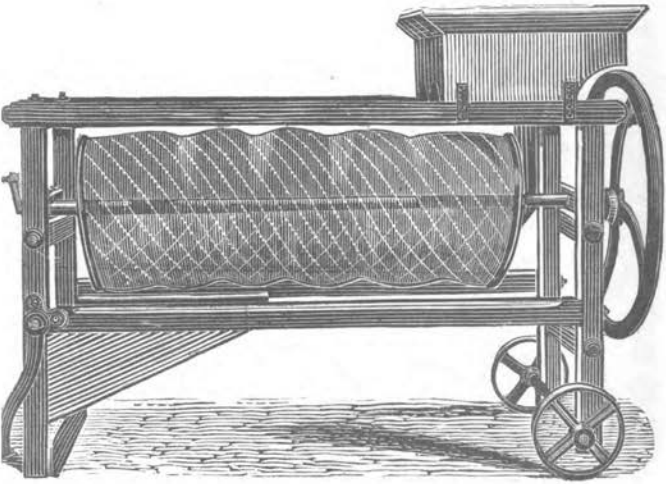


Fig. 39.

opened or closed with the adjusting handle to suit all kinds of grain or seeds.

Of special seed cleaners and seed-sorting machines for dealing with clover, rye-grass, and other small seeds, there are several; and as a rule they are more efficient for this purpose than the combined machines intended to dress either corn or small seeds.

Boby's Seed-sorting Machine (Fig. 40) aims at, and does to a very great extent improve clover seeds by separating dirt and weeds, as well as plantain and rye-grass; and by changing riddles it will successfully act on goose-grass, hair-grass, &c.

This screen has not the usual sifting motion, but the wire or perforated bed is acted upon by means of a spring hammer, which agitates or imparts a tremulous motion to the bed, and has the effect of making the seeds present every point of surface to the riddle, and gives all possible chances of their passing through.

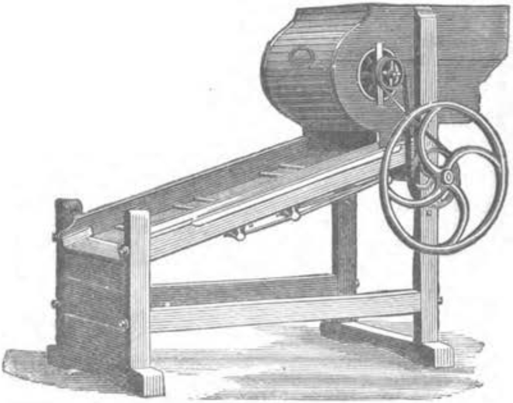


Fig. 40.

Richardson's Seed Cleaner, which was brought into notice at the trial of seed-cleaning machines, held at Edinburgh by the Highland and Agricultural Society in the spring of 1883, is fitted with a set of three or more sieves placed in steps or stairs in the same sloping frame. This frame oscillates lengthways with a heaving sort of motion, by which a heavy-headed seed such as wire grass, when dropping from one sieve to another, is made to fall on its heavy head, and so pass more readily through the meshes of the sieve. Thi machine is chiefly intended for rye-grass seeds, and to do the chaffing, riddling, and screening at one operation. By changes of sieves and riddles it may be made to dress other seeds, such as turnip-seeds and clovers; but it appeared to be less successful with the clovers than with the rye-grass seed.

Awners or Hummelling Machines.—These machines are for the purpose of removing the awns from the barley, and are indispensable on a barley-growing farm, if a non-finishing threshing-machine is employed. The old plan of doing this was to put the barley through the threshing-machine a second and third time; but this injured the grain for malting, and was besides a laborious process. The addition of an awner to the threshing-machine, enabling barley to be turned out clean at one operation, as easily as all other grain, was, therefore, a decided step forward.

One form of barley awner is that already described in connection with Clayton and Shuttleworth's threshing-machine. It consists of a shaft studded with knives and adjustable beaters, revolving in a cylindrical casing. This is the class of awner with which most of the modern finishing threshing-machines are fitted; and it is equally suited for the purpose when made separate and worked independent of the thresher.

Boby's Barley Hummeller is illustrated in Fig. 41. The barrel is made of iron, and a strong wrought-iron spindle runs through the centre, on which is fixed a series of knives which revolve at great speed. These knives are so shaped that although the barrel is fixed perfectly straight on the frame (and not inclined like those generally in use, which have a tendency to let the barley escape before it is properly awned) the knives of themselves force the barley along the tube, so that it is impossible for the corn to escape from the spout until it has been subjected to the action of the whole of the knives in the barrel; and by the time the corn reaches the outlet it is effectually deprived of the

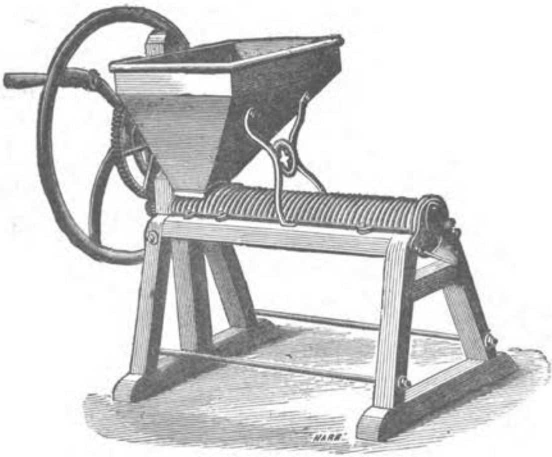


Fig. 41.

awns. The machine is very simple, and can easily be worked by one man.

The same hummeller is made of a size suitable for being worked by power, and adapted for attaching to any large portable corn-cleaning machine, or for fixing in barley stores. This machine will effectually deprive the kernel of the horn or needle without damage to the grain at the rate of 120 bush. per hour. It is fitted with 9-in. fast and loose pullies, which should be driven at about 250 revolutions per minute.

CHAPTER XI.

BARN UTENSILS AND APPARATUS.

THE usual form of barn shovel is shown in Fig. 42. It is made wholly of wood. The one here illustrated, which is Bobey's manufacture, has the handle worked up separately and secured to the blade by two bolts and wrought socket plates, and by unbolting the handle a flat turning blade can readily be substituted for the deep blade if desired. The blades are 20 in. by 13 in., and made of thin, light, hard wood.

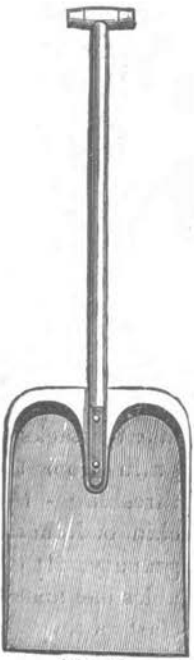


Fig. 42.

An article which is useful alike in the barn and in the chaff-bin is the hand-sieve (Fig. 43), for sifting dust

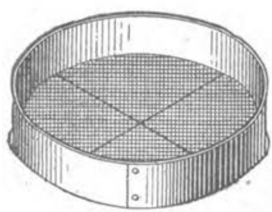


Fig. 43.

and small seeds from corn and cut chaff. They are now usually constructed with wove wire bottoms, and are made with the wire mesh of various sizes to suit different kinds and qualities of grain.

Boby's Improved Grain-sampler (Fig. 44) ought to be extensively used by farmers and corn merchants. By means of this instrument samples of grain can be drawn with the greatest facility from the middle of a large heap, or from the interior of a cargo, so insuring the purchaser of buying equal to sample. In this way also temperature and condition of large quantities of grain may be frequently tested, without unnecessary trouble or loss of time.

Fig. 44.

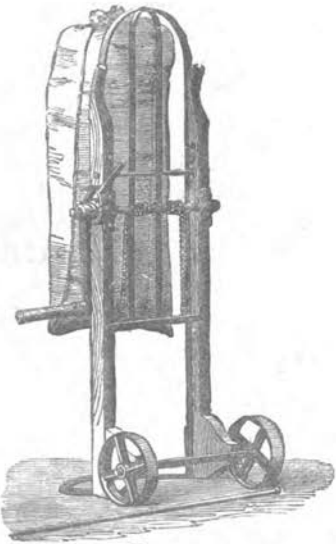


Fig. 45.

Sack-lifting Barrow. — The sack-lifting apparatus is a valuable addition to the old plain sack barrow, in moving sacks of grain from the threshing-machine or from the granary. It enables one man to remove the sacks from the machine as fast as they are filled, and without the assistance that would otherwise be necessary for getting them on to his back. The illustration shows the positions of the barrow, by Clayton and Shuttleworth, with a sack partly raised. These barrows are strong and durable, and by means of a wheel and pinion motion in connection with the raising apparatus, are also very easy to work.

Sack - Holders.—Gilbert's Improved Patent Iron Sack-holder (Fig. 46), manufactured by Richmond and Chandler, is a useful labour-saving invention. It holds the mouth of the sack wide open, forms a rest for the

Fig. 46.

vessel used in filling, saves the expense of an assistant, and is very light, portable, and cheap, costing only £1 3s. At a small extra cost the sack-holder can be had on wheels, which, when the sack is filled, forms a neat and convenient barrow for conveying it where wanted.

An American bag-holder on platform scales is shown in Fig. 47. It consists of an iron hoop, nearly as large round as a corn sack, with several small hooks on it, at equal distances, to which the bag is suspended. Attached to the hoop is an iron rod, with a hook end which slips into a socket on the front of the upright enclosing the rods that run from the platform of the scale to the weighing beam. The shank should fit loosely in the socket, to let the hoop tilt down, so that the bag can be readily unhooked. There is an eye-bolt in the hoop where the iron rod joins it, and a rod with a hook on the upper end is fastened into it. This rod reaches to a staple fastened above the socket on the upright of the scales. When the hook on the end of this rod is slipped into the staple, it lifts the hoop to a level position, and is of sufficient strength to hold a bag of grain. The hoop should be high enough to allow a bag to clear the platform of the scales. When filled, the hook of the sustaining rod is released, and lets the hoop tilt downwards, until the bag rests on the platform. A tin funnel or hopper may be attached to the hoop, if desired, as in the engraving.

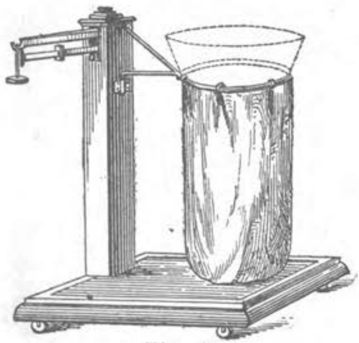


Fig. 47.

Sack-hoisting Machinery.—Presuming farmeries to be constructed in their arrangements something more nearly to mills and manufactories, there will be required an easy method of hoisting sacks and other weights from the lower to the upper floors or granaries. A common crane and windlass is often used, but this is an exceedingly slow process, and not always convenient.

In flour-mills it is necessary to have the means of hoisting with rapidity and ease the sacks of corn from the lower floors to the higher, for the purpose of emptying it into the hoppers for supplying the stones; or to raise the meal from the bins on the lower floors to the upper, to be passed through the dressing machine; and for this purpose a machine called a sack-tackle or hoist is used. It is exceedingly simple, and answers the purpose admirably.

Sack-tackles are constructed in several different ways, but the one most in use is as follows:—

In the roof of the building is placed a wooden framework, moving with hinges at one end; across this frame is placed a shaft, or spindle, having upon it a wheel, or pulley, and a barrel to carry the chain or rope; in a line with the pulley in some direction, and upon a shaft always kept running, is placed another pulley; over these two pass a strap, made so loose that the pulley in motion does not give motion to the other. At one end of the sack-tackle frame is a piece of iron, set up with a strong spring to press it forward, and having a projecting notch or ledge on the face of it. We have before observed that one end of the frame was movable; when a sack is required to be hoisted, one end of the wooden frame, and with it the shaft carrying the pulley and chain-barrel, is lifted; the strap then works tight on both the running and the other pulley, and the chain or rope works round the barrel. The frame is lifted by a cord running through a small pulley above, and passing through a hole in each floor beside the sack-traps, through which the sacks are hoisted. When the frame is lifted by this cord, it passes up the face of the iron spring till it arrives at the notch, upon which it rests. The cord by which the frame is lifted is called the striking-in line. As long as the frame remains on the notch, the barrel continues to revolve and wind up the chain. This of course requires another arrangement to again slack the strap and stay the action of the winding barrel; this is effected by simply having a line to draw back, the spring, upon which the frame descends to its former position. This line is carried down through the floors beside the other, and is called the striking-out line. At the lower end of the chain is a ring large enough to admit of the sack being passed through double; a loop is thus formed which takes hold of the neck or tie of the sack; the striking-in line is pulled with a jerk, and the sack ascends to the required height; the striking-out line is then pulled, and the sack drops on to the floor above the traps.

In some sack-hoists the strap is tightened by a lever pressing against it; the frame and barrel then being stationary, nothing taking place but the tightening of the strap by the lever.

In others a hollow cone is used, working on to a solid one, which is always moving; but the ordinary one we have attempted to describe.

Weighing Machines.—It is of course indispensable for every farm to be provided with beam and scales, or other apparatus, for ascertaining the weight of grain, wool, and other commodities, in quantities varying from 1 lb. to 3 cwt. But, besides this, it is very desirable to have a machine by which not only turnips, hay, manures, &c., can be weighed in cartloads, but by which also the live weight of pigs, sheep, and bullocks can be ascertained.

The common steelyard is a lever of the first order, in which the arms are unequal, and the same weight is used to weigh different substances by varying its distance from the fulcrum. To graduate the steelyard, first find the zero subdivision by bringing the unloaded instrument into equilibrium by shifting the weight or counterpoise. Put then on the hook, or in the pan, such a number of even pounds as will push the counterpoise to the greatest distance it can go on its arm for even pounds, and divide the distance between this last position and the zero point into as many equal parts as there are then pounds on the hook. The points of division so obtained are the position of the counterpoise for the several pounds up to that number, and for half and quarter pounds, &c., these divisions must be subdivided.

CHAPTER XII.

FOOD-PREPARING MACHINES.

THIS division of our subject embraces a large assortment of machines, including as it does turnip-cutters and pulpers, root-washers, oil-cake breakers, corn-bruisers, grinding-mills, chaff-cutters, and steaming apparatus. No very striking improvements have been introduced amongst any of them lately.

Turnip-Cutters and Slicers.—Machines of this class are now largely superseded by the more approved root-pulpers, especially where the roots are to be fed mixed with chaff or corn. For sheep feeding in the turnip-field, however, the turnip-cutter is still, and will probably long continue to be, extensively used.

Two different forms of turnip-cutters are chiefly in use at the present time—the barrel and the disc forms.

Of the former class, Gardner's machine in its improved form is the best. Fig. 48 represents a section through the barrel and hopper of a Gardner machine showing the cutting principle. Cylinder turnip-cutters were in use long before Gardner patented his machine, but they only cut large and very unequal slices. Th knife in them was extended entirely across the cylinde with an unbroken edge, and had the cross knive placed under the slicing knife, of which there wer two, and raised above the cylinder the thickness of the slice cut.

Gardner's improvement consisted in the arrangement of the face of the cutting-knife into sections of a width equal to the required cut of the root—each knife

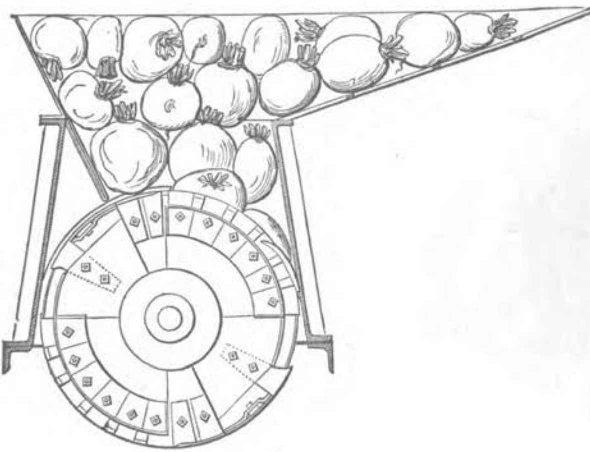


Fig. 48.

cutting on the front and side edge at right angles with it, and placed one above another till they meet in the centre, the angles of the knife retiring *en echelon* from the front to the centre. Two of these knives are placed on the cylinder in the cut, and against the front plate is shown a ledge which causes the last piece of the turnip to be cut instead of falling through unslit. This cutting of the last slice has, however, never been fully effected in any but the very latest and most improved machines. In Samuelson and Co.'s Improved Gardner Turnip-cutter, of which Fig. 49 presents a general view, this object is skilfully accomplished by a perforated guard or shield fixed underneath the barrel or cylinder, which prevents any piece that may escape uncut from the front cutting-plate from falling into the basket with the cut roots, and carries it round to the hopper again to be forced through the knives by other roots. The action is perfect, and the result is a great practical improvement in the economy of cutting up roots, as it avoids a certain waste which has hitherto occurred in most machines, owing to the last portion passing into the basket—a large piece, or nearly all, rind, and which is in consequence refused by the sheep and wasted.

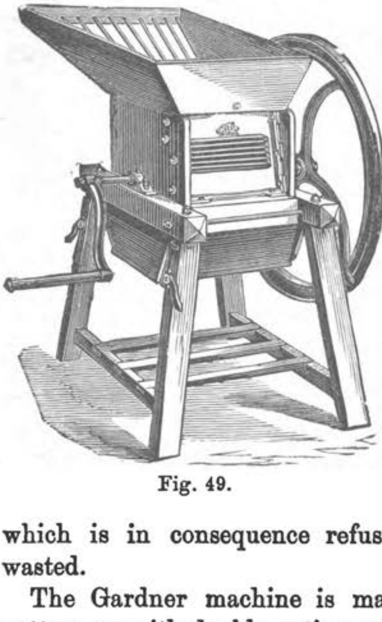


Fig. 49.

The Gardner machine is made with single-action cutters, or with double-action cutters, as wanted to cut either for sheep or for cattle, or with reversible motion to cut for both sheep and cattle. For cattle the machines are fitted with slicing knives only, cutting $\frac{5}{8}$ of an inch thick, and the whole width of the turnip. For sheep, the machines are fitted with knives cutting finger pieces, each $\frac{3}{4}$ of an inch wide and $\frac{5}{8}$ of an inch thick.

All other roots, as mangolds, carrots, &c., may be cut with it equally well,

It is a great convenience to have the machine mounted on wheels and fitted with large drop handles, so that a boy can move it unassisted in the field.

In the turnip-cutters on the disc principle, a series of knives are placed in the face of an iron disc by screws. The turnips are placed in a hopper set at an angle, so that they may press by their own weight against the disc.

Fig. 50 is an illustration of Hornsby's Turnip-cutter on the disc principle. It will cut as rapidly and with even a less expenditure of power than the Gardner pattern cutters, with less weight to move from place to place. By a novel arrangement of the knives upon the disc a great saving of power is obtained, together with unequalled regularity and uniformity in the slices. Each knife cuts a regular and full-sized piece parallel from end to end. Slicing knives for cutting slices for cattle feeding can be added. It has a large wrought-iron hopper, self-feeding, and screening the roots from dirt before passing them to the knives. It is fitted with convenient drop handles for carrying, or may be had mounted on wheels.

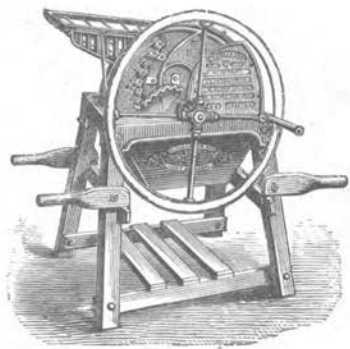


Fig. 50.

The Lever Ball Turnip-slicer (Fig. 51) is still much used in Scotland. It cuts the roots in large broad slices, and is only adapted for cattle feeding. There is but little economy, however, in feeding roots so cut. Experience is every day more in favour of pulping the roots for cattle and mixing with dry food.

Root-Pulpers.—For house feeding, of sheep as well

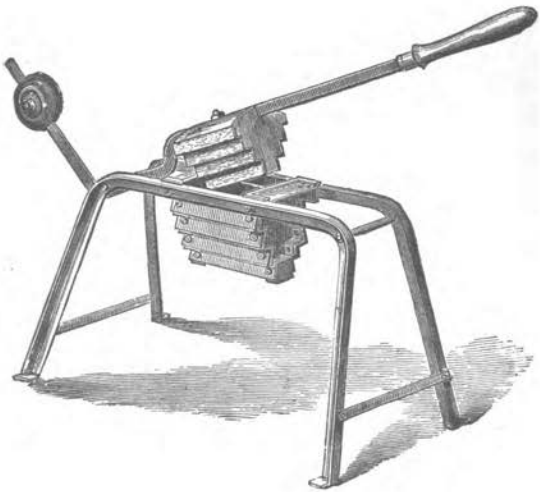


Fig. 51.

as cattle, the pulper is destined to entirely supersede the turnip-cutter, in districts where it has not done so already.

Pulpers are made both on the disc principle and on the barrel principle. The former, however, are by far the most extensively used, and very excellent machines of this class are now produced by many makers.

Fig. 52 represents one of Richmond & Chandler's new Disc Root-pulpers, with the side plate removed showing the arrangement of the knives or cutting points upon the disc. The knives are adjustable to pulp coarse or fine as required; and the shape of the hopper and the positions of the knives are such as to insure perfect feeding and a regular sample of pulp.

Fig. 52.

The pulpers to be worked by hand are usually fitted with four knives, as in the illustration, each knife consisting of upwards of twenty cutting points. The machines intended to be worked by power are fitted with six or more knives, and have upwards of a hundred cutting points.

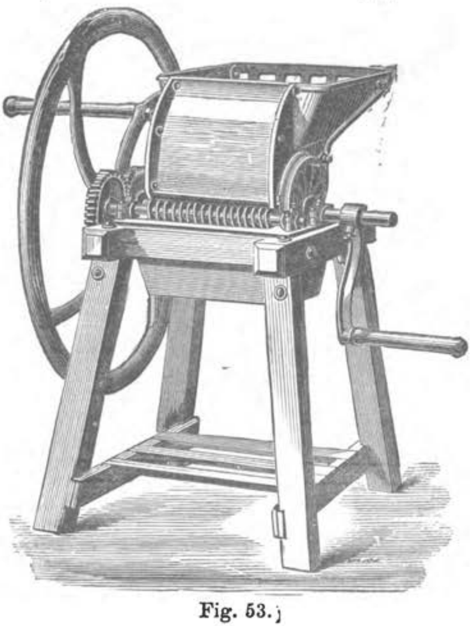


Fig. 53.

A Barrel Pulper, one of Bentall's improved machines, is shown in Fig. 53. This is a large machine for horse, steam, or water-power, and is capable of pulping from 4 to 5 tons of roots per hour. The knives, which are of the best steel, are fastened by means of a wooden wedge, and can easily be replaced in case of breakage. This description of machine is extensively used for pulping cabbages.

Combined Pulper and Slicer.—An exceedingly useful

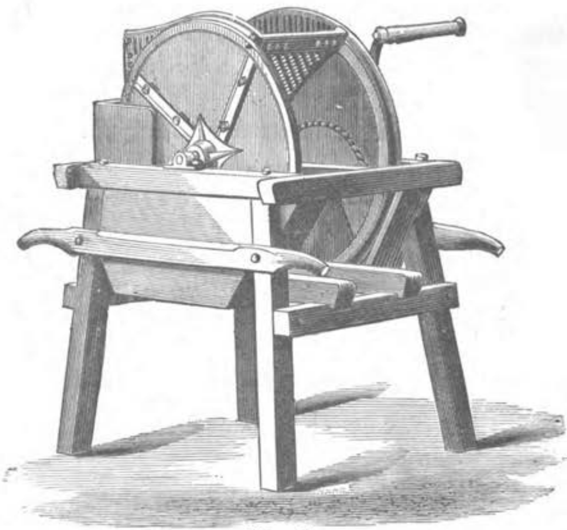


Fig. 54.

machine of this class has been brought out by Vipan and Headley. A general view of it is presented in Fig. 54. The combined machine consists of two discs with reversible hopper, and can be used either for pulping or slicing as required. The price of the combined machine is very little more than that of an ordinary pulper or slicer, so that in this respect it offers considerable advantage.

Root-Washers.—On root-growing farms a machine of this kind is very needful at times for dealing with roots when covered with dirt. It makes the roots more palatable to the stock, and it effects a considerable saving in time compared with washing the roots without the aid of a machine.

An ordinary practice is to put the roots into a large tub of water, and with a stick stir them about. The roots of course may be thoroughly washed in this way,

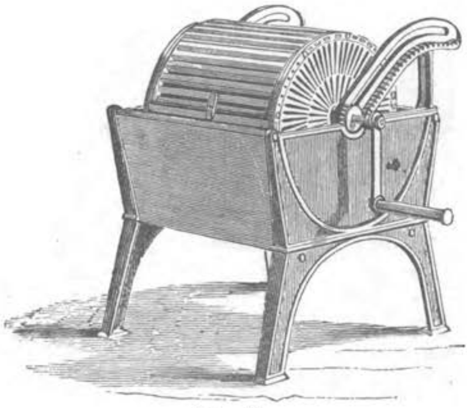


Fig. 55.

but they seldom are. There is no excuse for doing the thing badly and in wasting time over it besides, when such capital machines as those constructed by Richmond & Chandler and by Crosskill are to be got at moderate prices.

Richmond & Chandler's Root-washer (Fig. 55) consists of a trough, within which is a cylindrical cage, supported in bearings fitted to the sides of the trough, from which rises a curved rack. The spindle of the cylindrical cage is fitted with a pinion corresponding to the rack. The object of this arrangement is to raise out and readily discharge the vegetables when sufficiently washed. The price is 4 to 5 guineas.

Crosskill's Archimedean Root-washer (**Fig.** 56) consists of an open cylinder, partly immersed in water and containing an archimedean screw. The potatoes, roots, or other vegetables, are put in by a hopper, and as long as the cylinder is turned in one direction, they remain

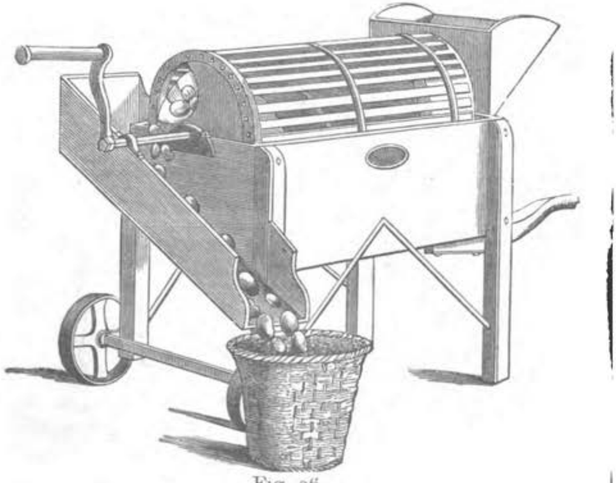


Fig. 56.

in it and are well cleaned, but when the handle is reversed the archimedean screw brings them out of the cylinder, without the necessity of lifting it out of the water as in the other machine.

The two legs at one end of this machine are placed upon wheels, and at the other end are two barrow handles, which enable it to be wheeled from place to place with great ease. The price varies from £6 to £8, according to the size of the machine.

Potato-Separator.—This is a machine used for the purpose of screening or separating potatoes into sizes ready for sale. It is an exceedingly useful machine on farms where potatoes are largely grown, as sorting them properly insures the farmer a greater profit than selling them mixed large and small. When this sorting is not done by the grower, it is done by the potato dealer, who of course reaps the additional profit thus neglected by the farmer.

Potato-separators have usually been constructed

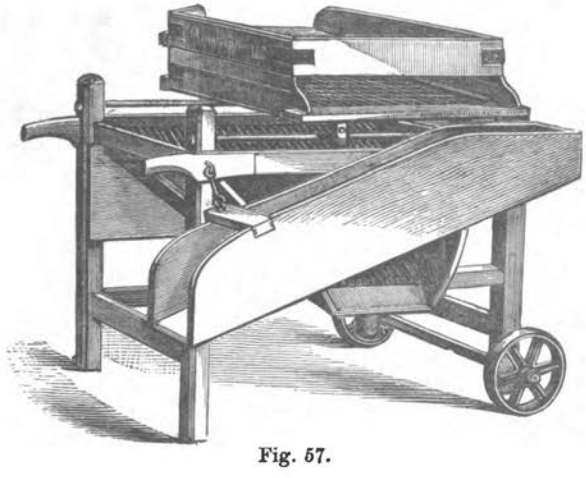


Fig. 57.

with three sieves or screens of different sized meshes, placed one under another, with a shoot to carry the potatoes from each screen to a separate receptacle, as in Fig. 57. The screen also entirely frees the potatoes from all dirt, straw, or other rubbish. This machine is made by the East Yorkshire Cart and Waggon Company, Limited, who also supply other kinds of potato-separators and washers.

Oil-Cake Breakers. — The principle of all these machines is that of two rollers, armed with knobs or teeth, which can be set to any required distance from each other. They will break oil-cake to any size suitable for sheep or cattle.

Fig. 58 presents a view of Samuelson and Co's., Improved Oil-Cake Breaker. It is provided with a heavy fly-wheel of large diameter, enabling it to be worked with very little power. The rollers are readily shifted by the aid of a handle, and by this means the cake can be broken into various sizes as desired. One side of the hopper can be set back in order that broken pieces of cake may be fed into it with a shovel or by any other convenient method. The dust sifts through into a tray under the machine, whilst another box receives the broken cake. Both of these boxes are provided with each machine. The cost complete, is £3 3s.

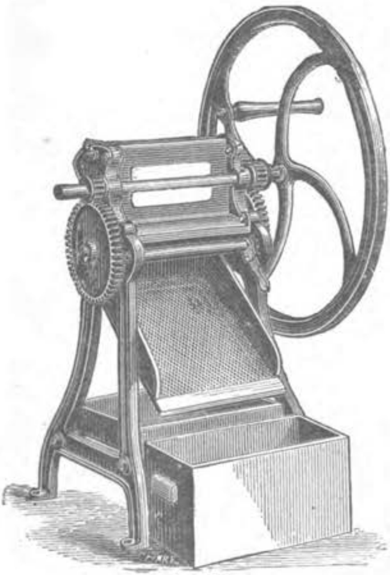


Fig. 58.

Corn-Crushers and Grinding-Mills.—Bruised corn is well known to be more nutritious, and consequently more economical, than grain fed in its natural state.

Oats will go one-half further in measure after being well crushed, while the horse is put into better condition for work at less expense. If fed uncrushed, oats are swallowed without mastication, as is obvious from their being voided in a whole state, and consequently of little or no benefit to the animal.

The most conclusive experiment on this subject is that which was performed by the London Omnibus Company, who are the owners of 6,000 horses, the one-half of which were confined to one kind of feeding, namely, that of bruised oats, cut hay and straw, and the other half to whole oats and hay. The ration allowed per day to each horse, according to the one system was—bruised oats 16 lbs., cut hay 7½ lbs., cut straw 2½ lbs. The quantity allowed according to the old system was—unbruised oats 19 lbs., uncut hay 13 lbs. There is thus a saving of 6 lbs. on the feeding of each horse, and this saving is not merely in the quantity, but in the value of the articles employed, for we have straw in the former case substituted for hay in the latter. The money advantage in favour of bruised oats and cut hay is fully 2½d. per day for each horse, which is equal to £62 10s. per day for the 6,000 horses. And this saving was accomplished without any sacrifice whatever, for all the drivers and those having charge of the horses agreed that the difference in the condition of the horses was decidedly in favour of those fed on bruised oats and cut hay and straw.

For horses, fatting beasts and pigs, crushed corn is as efficient as fine meal, while the saving in the cost of preparation is manifest.

Kibbling mills intended to break the corn only and to make as little flour as possible, are, therefore, in most demand for crushing corn that is to be fed to stock.

Very excellent machines of this class are supplied by Richmond and Chandler, Marshall, Garrett, Ransomes, Bentall, and other makers.

A cheap and efficient double-action Kibbler by Richmond and Chandler is shown in Fig. 59. The barrel, which is of steel, has two cutting edges; and a cutting plate of hard metal is fitted on each side of the same, so that when turned in one direction it will kibble beans, peas, and maize; and when turned in the opposite direction, it will kibble barley and oats. The machine is made in larger sizes for horse, water, or steam-power. It is also made with a single-action steel barrel; in which case it is provided with two cutting plates of hard metal, one for beans and maize, and the other for oats; and the hopper is hinged, so that when the plates require changing it can easily be turned back.

Fig. 59.

Grinding-mills are less useful on the farm, but where steam-power is employed one of these mills is an acquisition, for the farmer can then grind flour for domestic use, as well as grind his corn into meal for his cattle and pigs.

Nothing has yet been invented which will grind corn so well as millstones, or that will so thoroughly meal it and prepare it for cattle food. English grey stones are suitable for grinding barley, crushing oats, or kibbling maize and beans; but for producing fine wheaten flour, French burr stones are necessary.

One of Ransome's grinding-mills is shown in Fig. 60. It is fitted with a bean-cutter, to crack beans, peas, maize, &c., to a small size before grinding.

The quantity of corn ground by this machine in a given time will vary according to the required fineness of the flour. With a pair of 48-in. stones, 8 to 12 bushels of barley per hour may be ground to fine meal; if only required to be kibbled or partially broken a much greater quantity may be done.

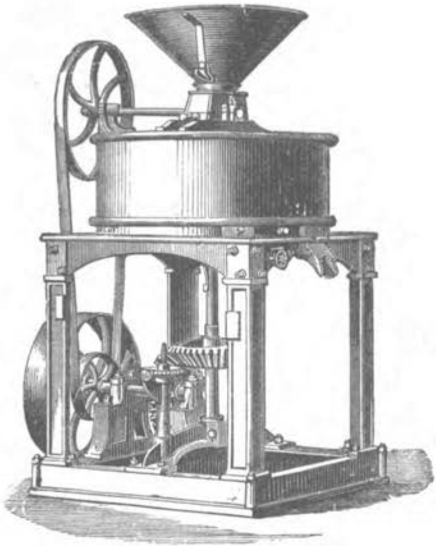


Fig. 60.

Chaff-Cutters.—It is unnecessary to say much about the many and great advantages to be derived from the use of the chaff-cutter. The results of feeding with cut fodder are so visible that no stable or feeding shed should be without one, however few the animals to be fed.

In all the improved chaff-cutters the knives are attached to the radial arms of the fly-wheel, and the uncut fodder is brought up to the knives by a very effective feeding apparatus, consisting of toothed rollers working into each other in such a manner as to insure a regular feed, and prevent all choking.

Fig. 61 represents one of Richmond and Chandler's machines, which are made in sizes adapted either for hand, horse, or steam-power.

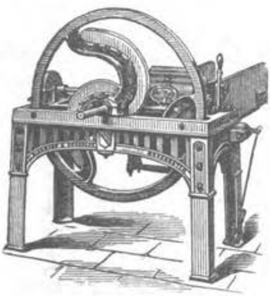


Fig. 61.

The mouth-piece is adjustable, and can be opened or closed (by means of a simple hand-screw on the top) to suit the different kinds of material to be cut. This arrangement not only renders choking an impossibility, but insures a regular sample of chaff.

The hopper can be fitted with a self-acting endless web, an advantage when the machine is worked by power and short material has to be cut; but the great assistance afforded by it is more marked in the larger sizes of machines.

The old lever and weight are abolished and spiral springs substituted, which give an increasing pressure on the feed as it becomes thicker. This is not the case with the weight or lever.

This machine cuts two lengths without change of wheels by merely moving a handle. It can be fitted to cut any two lengths of chaff, from $\frac{1}{8}$ of an inch upwards. The long length will always be just double the short.

The same handle which alters the length of cut also acts as a stop motion, instantaneously arresting the progress of the rollers. To reverse the motion or draw the feed quite back into the hopper the attendant has only to pull round the wheel at the end of the machine, which can be done while the fly-wheel is running at full speed.

In Crowley and Co's. Chaff-cutter, Fig. 62 (Samuel Edward's patent) the whole of the working arrangements, namely, stopping, reversing the rollers or feed, and varying the length of the cut, are under the control of one starting lever. A travelling web or feeding apparatus is fitted, when required, inside the hopper of each machine, the action of which web is also under the control of the one lever. This safety appliance offers perfect security to the man feeding. In case of his having both hands caught in the feed, his body would be drawn against the lever in question, which would instantly stop the machine. A further push with the shoulder against the same lever reverses the feed and frees the man. The largest size of this machine has a heavy fly-wheel, upon which are fitted three knives. This machine, running at 200 revolutions per minute, will cut upwards of 4 tons of $\frac{3}{8}$-in. chaff per hour.

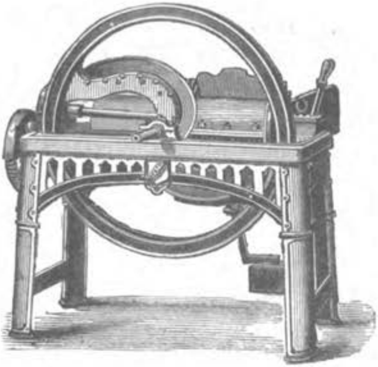


Fig. 62.

Any of the larger chaff-cutting machines are suitable for cutting up grass or other green stuff to be made into ensilage.

The special Ensilage-cutter (Fig. 63) manufactured by Bust, of Winterton, is better adapted for such work. It is a large machine fitted with five knives, and a roomy feed-board, and is specially adapted for being driven direct from the fly-wheel of a portable engine.

If placed near to the silo, waggons can be driven up alongside, and the loads thrown direct on to the cutter feed-board, when it will reduce the product treated to chaff at a tremendous rate, and also throw it into the silo as it is cut, thus saving a great amount of labour.

This machine can be provided with sifting and bagging apparatus, and may be used in connection with a steam threshing-machine, driven from a pulley on the drum-shaft, when the straw, falling from the machine

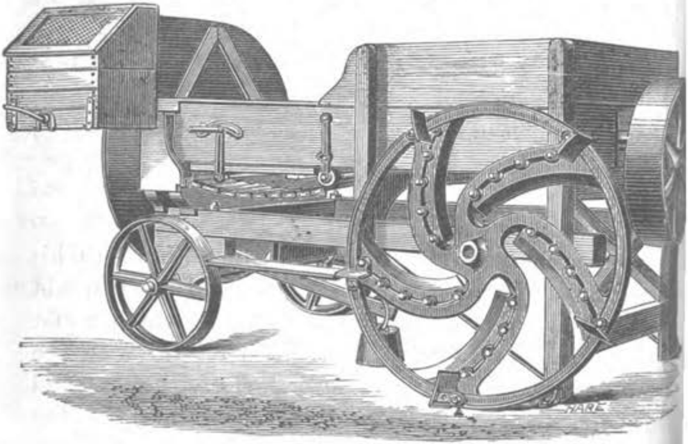


Fig. 63.

shakers on to the cutter feed-board, is reduced to short chaff, has the dust blown from it, and is delivered into bags as fast as it is threshed. A chaff-elevator, and a salt-sprinkler can also be appended to the cutter, when it is desired to deliver the chaff direct into the top doors of barns or chaff-houses, and to stow it away for future use.

Clayton and Shuttleworth's Combined Chaff-cutter, Sifter, and Bagging-machine, for working in conjunction with their threshing-machine, has already been alluded to. The machine is illustrated in Fig. 64. It is one of the greatest savers of labour on a large farm, and is capable of cutting the straw as fast as it is threshed: it not only cuts the chaff, but sifts it, and delivers it into bags ready for removal. It does all this, too,

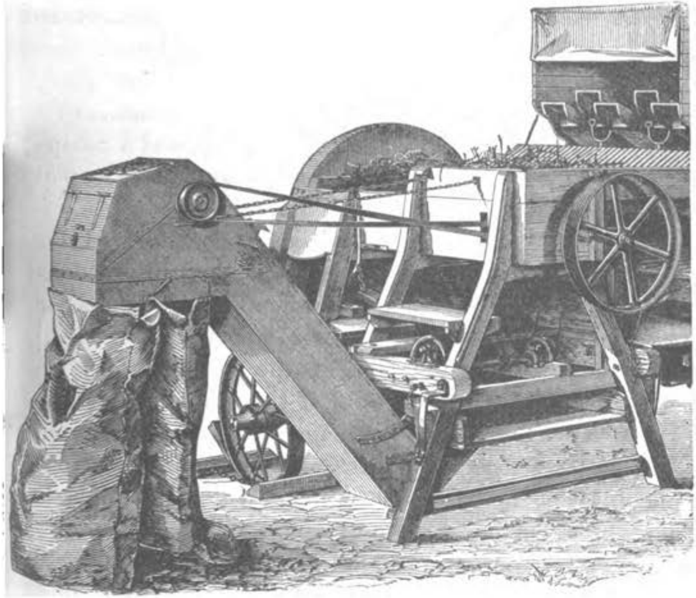


Fig. 64.

with fewer hands than would be required to stack the straw as it comes from the thresher, even with the help of a straw-elevator.

Three lengths of chaff can be cut at pleasure by simply changing the gear wheels which drive the feed rollers; these lengths are $\frac{3}{16}$ in., $\frac{3}{8}$ in., and $\frac{5}{8}$ in.; or litter may be cut in lengths of say 1 in. to $3\frac{3}{4}$ in. by removing all the knives, except one, from the fly-wheel.

This machine is equally well adapted as an ensilage-cutter, in which case it is driven direct from the fly-wheel of a portable engine, instead of by a pulley placed on the drum-spindle of the threshing-machine, when it is used in connection with the latter.

Maynard, Crowley, and others, also manufacture combined cutting, sifting, and bagging-machines.

Steam Food-Preparing Apparatus.—The ordinary apparatus used for steaming food for stock consists of a copper or boiler for generating the steam, and a receptacle into which the food is placed to be acted upon by the steam.

In homesteads where a fixed engine is employed for threshing and other purposes, it will probably be convenient to make the same boiler supply the coppers for cooking the food. In other cases, a complete steaming apparatus to suit the size of the holding may be arranged separately. Several of these are now manufactured by different houses, properly constructed for the purpose. Among these, Barford and Perkins' apparatus is to be reckoned one of the best, simplest, and most economical. Being self-contained, it requires no brick-work whatever, and can be easily fixed by a farm labourer in a few minutes. It is adapted for steaming hay, chaff, roots, corn, linseed-meal, and other compounds, and for boiling milk and water for pigs, horses, and cattle.

Fig. 65 represents a set of this apparatus, capable of steaming all the food for about twenty-four cattle and as many pigs, at a cost in fuel of less than one shilling per day. Thousands of tons of potatoes have been steamed by it at a cost of fuel not exceeding one farthing per cwt. It consists, as will be seen, of a wrought-iron steam generator and two 6-bushel revolving root or chaff

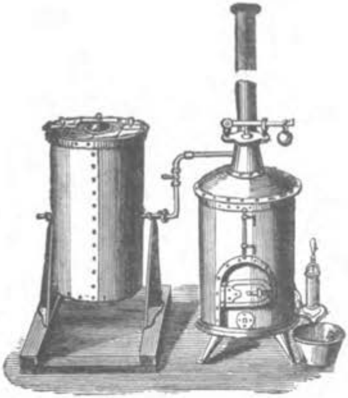


Fig. 65.

pans. Where much hot water or milk is wanted, a 60-gallon strong galvanised-iron compound or boiling pan can be substituted for one of the revolving root or chaff pans. The price, complete with two pans, is £23.

CHAPTER XIII.

ARRANGEMENT OF BARN MACHINERY.

Fixed barn works, although a comparatively recent invention, are already becoming a thing of the past. The ponderous fixtures found in many barns, especially in the northern parts of the kingdom, are now judged unnecessary, both on account of their expense, and because they absorb too much power for the amount of work they perform.

As an illustration of how farm customs change, the judges' report on Derby Prize-farm Competition in 1881 mentions that the fixed threshing-machine which the tenant of the first-prize farm put up less than twenty years ago is now seldom used. It is found cheaper to hire a portable engine and machine, and thresh the stacks where they stand, rather than remove them to the barn, although the rick-yard adjoins it. Upon the second-prize farm is a capital fixed chaff-cutter, but it is considered more economical to cut up the straw at the same time that it is threshed in the field, and to remove the chaff in large bags direct to the buildings, where it is safely stored until it is wanted for the cattle.

Beyond the question of convenience, the great expense of putting in a fixed engine and threshing-machine has made it a matter that few farmers cared to undertake, seeing that the landowners in many cases would not take them off their hands at valuation, and the loss by removal being so considerable.

Besides, in nearly every case the arrangement of fixed barn machinery has had to be made to suit an existing building, and cannot, therefore, be said to be the best, or so complete as it might be if the building were made to suit the machinery.

For these reasons farmers are now very generally in favour of portable engines and movable, or at least only semi-fixed, machines.

As an example of fixed barn machinery, however, we give in Figs. 66 to 68 an arrangement planned by Messrs. Clayton and Shuttleworth, and which plan they have followed in various erections.

The plan shows the machinery worked by a steam-engine, but of course the same arrangement can be carried out with water-power where such is available.

Mode of Transmitting Power.—In the early threshing-machine, the power was transmitted through gear, that is, through a train of toothed wheels. In the modern machine the power is taken direct from the fly-wheel of the engine to the drum, upon the axle of which is a metal sheave: all the other parts of the machine are also driven by belts, so that when it works, noise is reduced to a minimum.

In some winnowing-machines also there is no gearing, the motion being communicated to the fan, riddles, and screen by means of cords and bands working round pulleys, and driven from cranked fan-shaft.

And where a steam-engine is employed, although any single machine is perhaps best driven direct from the fly-wheel, to make a complete and convenient barn it should be fitted up with an intermediate shaft and

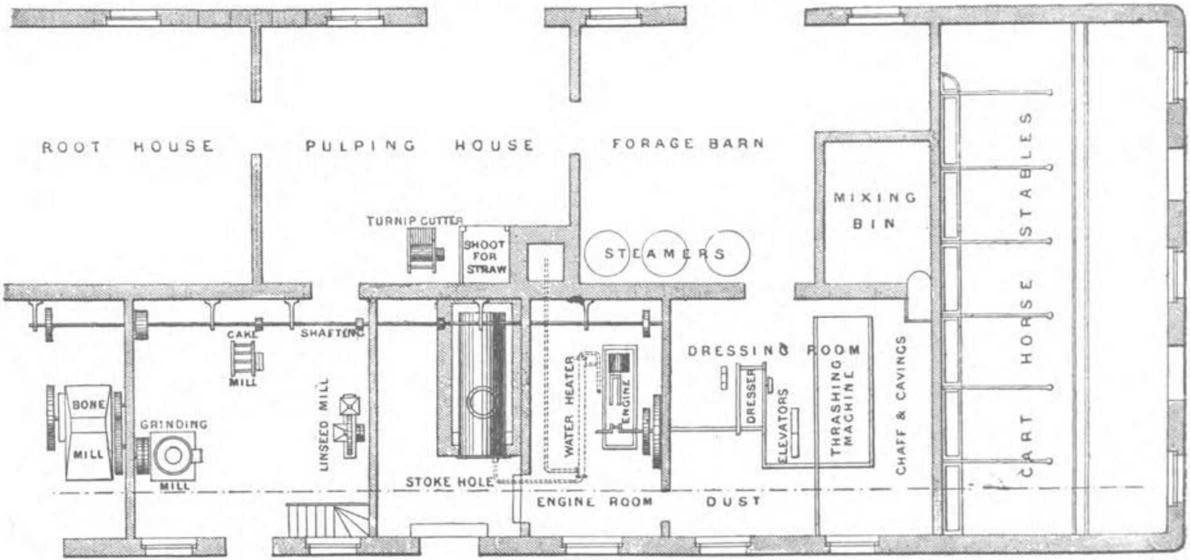
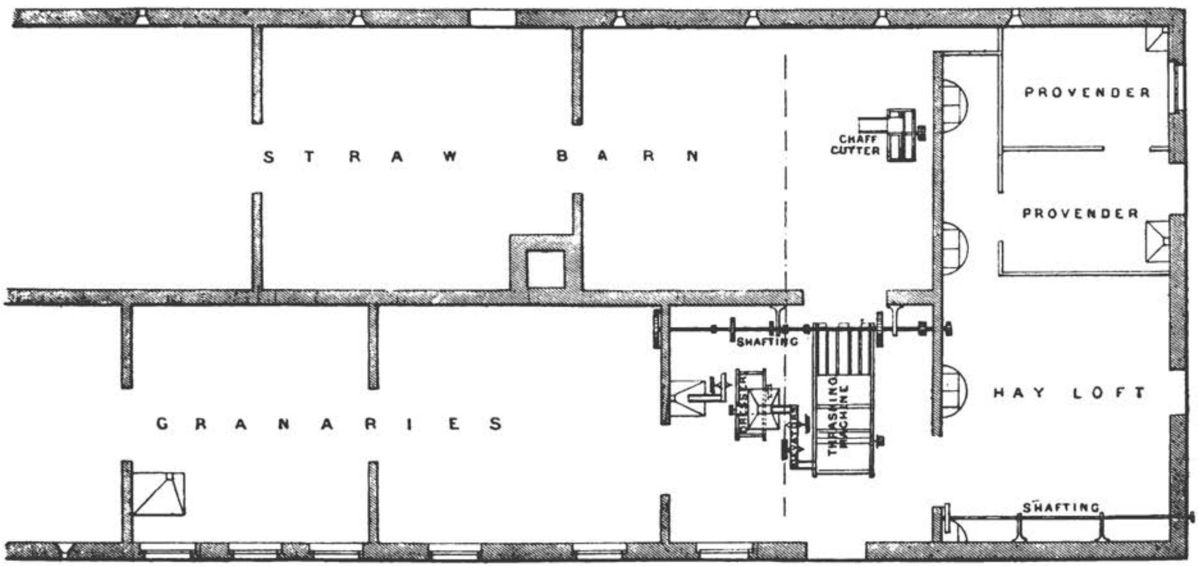

ROOT HOUSE
PULPING HOUSE
FORAGE BARN
TURNIP CUTTER
SHOOT FOR STRAW
STEAMERS
MIXING BIN
CAKE MILL
SHAFTING
BONE MILL
GRINDING MILL
LINSEED MILL
STOKE HOLE
WATER HEATER
ENGINE
ENGINE ROOM
DRESSING ROOM
DRESSER
ELEVATORS
THRASHING MACHINE
CHAFF & CAVINGS
DUST
CART HORSE STABLES

Fig. 66.


STRAW BARN
GRANARIES
CHAFF CUTTER
PROVENDER
PROVENDER
SHAFTING
DRESSER
ELEVATOR
THRASHING MACHINE
HAY LOFT
SHAFTING

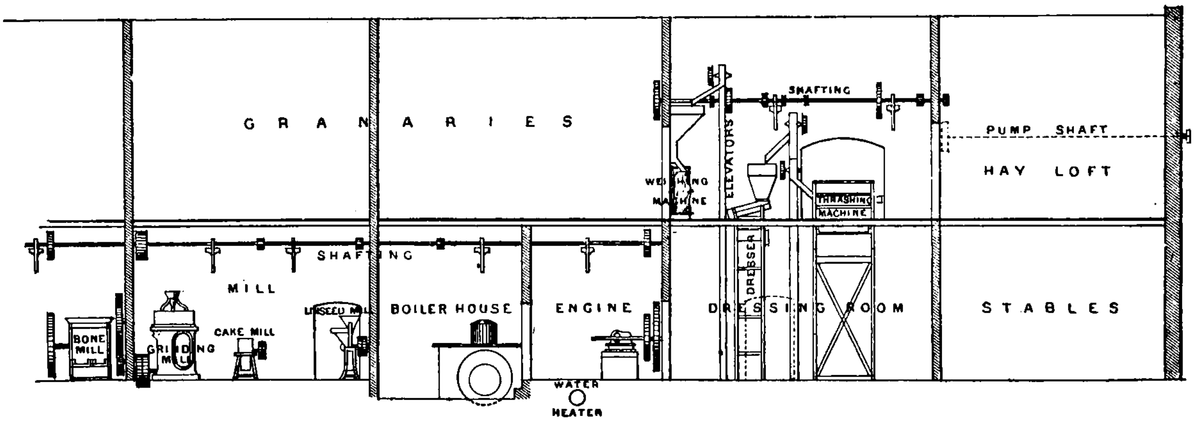

GRANARIES
SHAFTING
PUMP SHAFT
HAY LOFT
WEIGHING MACHINE
ELEVATORS
THRASHING MACHINE
SHAFTING
MILL
BONE MILL
GRINDING MILL
CAKE MILL
LINSEED MILL
BOILER HOUSE
ENGINE
DRESSER
DRESSING ROOM
STABLES
WATER HEATER

Fig. 67.

pulleys, from which may be driven not only the threshing-machine, but all classes of food-preparing machines, the circular saw, the bone-mill, or any other machinery requisite for the farm.

The line shaft may be carried either by pedestals, or in hangers, or on wall-brackets, as is most convenient. There are several lines of shafting employed in the arrangement of machinery shown in Fig. 67.

Horse or cattle gears furnish a convenient arrangement for driving small machines by animal power.

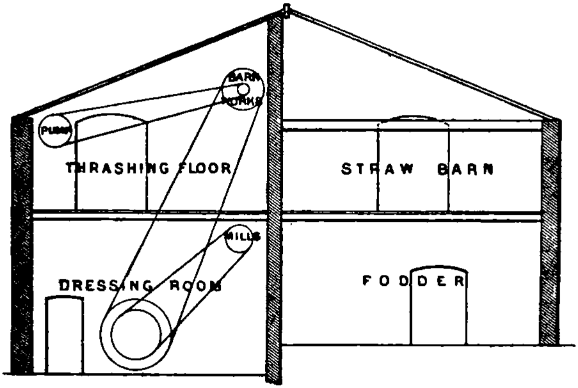


Fig. 68.

This is shown in Fig. 69, where a horse gear by Turner, of Ipswich, is arranged to work three different machines simultaneously.

As already remarked, it is now out of the question to think of threshing a large or even a moderate sized farm, with horse-power. On small occupations, however, a 1-horse threshing-machine is sometimes worked by means of horse gear, as is the case of B. Reid and Co's. small thresher, illustrated in Fig. 70.

Cost of Barn Machinery.—The following is an appoxi-

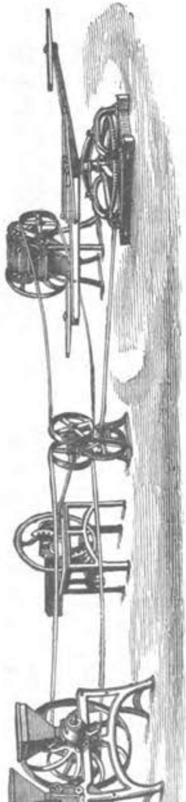


Fig. 69.

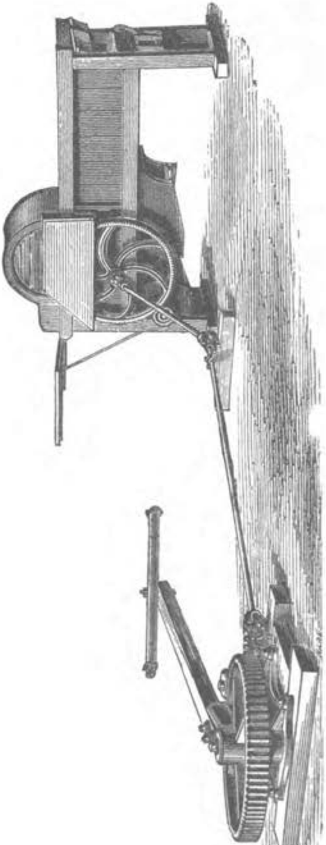


Fig. 70.

mate estimate for steam-engines and threshing-machines, &c., for farms of about—

	100 Acres.			200 Acres.			300 Acres.		
	£	s.	d.	£	s.	d.	£	s.	d.
Engine and boiler complete	71	0	0	85	0	0	105	0	0
Threshing - machine and fan	42	10	0	55	0	0	100	0	0
	116	10	0	147	0	0	208	0	0
Corn-bruiser	5	5	0	7	7	0	10	10	0
Chaff-cutter	6	0	0	8	0	0	10	0	0
Turnip - pulper and slicer	5	5	0	6	10	0	7	15	0
Grinding-mill . . .	16	16	0	16	16	0	16	16	0
Litter-cutter . . .		—			—		6	5	0
Circular saw, spindle, and bench . . .		—			—		15	0	0

CHAPTER XIV.

STACK COOLERS AND GRAIN DRYERS.

THE Neilson system of harvesting in the stack is an indispensable help to the making of good hay, and enabling the crop to be secured earlier than is possible without the exhaust-fan. No grain, also, should be stacked without making arrangements for operating upon the stacks with the fan, as, however well corn or hay is secured, heating to a greater or less extent always takes place, and by applying the fan the heated air can be withdrawn from the rick, which will improve the colour and aroma of the produce and make it more marketable.

In wet and late seasons, when there is little or no sunshine, the harvest fan will be found invaluable in enabling the curing of hay and corn crops to be completed in the ricks, when otherwise the produce must be completely spoilt, or greatly reduced in feeding value, by prolonged exposure to rain and weather.

This method of curing crops is based on the fact that air only is needed to dry the corn or hay after it is harvested, the sun having already done its work. All that remains to be done is to control the fermentation which takes place in all ricks, even when grass or corn is put together in neither a very green or damp state.

The stack is built with an air-hole or shaft in the centre, and pipes are laid to connect this shaft with a suction-fan or exhauster. When the fan is set going it speedily draws off the hot air and moisture from the central shaft, and as this creates a partial vacuum the external air is drawn in at all points of the rick, thus thoroughly drying the grass or corn however wet its condition may have been to begin with.

Fans of various descriptions are now employed for this purpose, most of them workable by hand-power; and being on wheels they are easily moved, so that one of them will answer for a good many ricks.

The pipes employed to connect the fan with the air-shaft are usually of iron, the diameter being 8 or 9 ins. The end of the pipe next the air-shaft is fitted with a damper which can be opened or shut at will.

It is unimportant whether the pipes are laid underground or on the surface of the ground, or at some height in the stack; but the air-shaft requires to be brought well down to the bottom of the rick, and should not be carried within 5 ft. or 6 ft. of the top of it.

An air-hole may be formed by using a corn sack stuffed with straw, and drawing it up as the rick is built, until the required height of the shaft is reached, when the sack is taken out altogether; or a framework of poles and laths may be used for the purpose.

The cylindrical form of rick is best, and it must not be too large. The smaller the rick the better, especially in the case of meadow grass, which, owing to the blades being so fine, packs closely and gets very dense. It is found that air cannot be rapidly drawn through the stack when the radius exceeds 8 ft. or 9 ft. If the rick is a long one it will require an air-shaft, or boss, for every 15 ft. or 20 ft. of length.

The temperature of the stack is best ascertained by the thermometer-stick, which does away with the necessity of having one or more thermometer-tubes in every rick. In a haystack the temperature should be kept below 100° Fahr.; and in a cornstack it should not be allowed to exceed 80° Fahr. If these temperatures are exceeded the fodder and the grain will be injured in quality and will lose in substance. Whenever, therefore, the temperature of the stack is found to reach 100° or 80°, as the case may be, the fan should be brought into operation. A very short time suffices to bring the heat of the stack down to the natural temperature; but the larger the volume of cold air drawn through the rick the better.

It is essential to the success of this method that, in haymaking, the grass be thoroughly shaken out in the field and allowed to lie a day or two and wither before it is carried. If that is done it may be stacked when not quite dry even, though that is not advisable in fine weather.

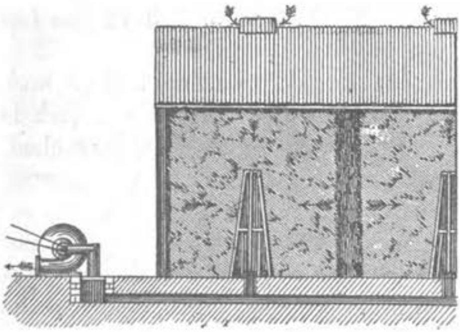


Fig. 71.

Unlike most valuable things, this one costs very little—the fan and all the fittings, complete, not more than £10 or £12; or about the value of 2½ tons of hay.

The illustration (Fig. 71) shows a longitudinal section of one of T. Pearson and Co.'s Single-span Iron Harvesting Sheds, 90 ft. long by 20 ft. wide and 14 ft. high to eaves, with hay stacked in bosses each 20 ft. long. An underground pipe with branches connects the different bosses with the air-vault under the exhaust-fan at one end of the shed. There is a damper, with rod to open or close at each boss. Ventilators are placed on the top of the roof over each boss.

The cost of applying Neilson's system to a shed of the above dimensions (90 ft. by 20 ft. by 14 ft.), capable of harvesting and housing about 96 tons of hay, will be as follows:—

	£	s.	d.
Cost of powerful fan for steam, water, or horse-power, capable of exhausting 108,000 cubic ft. of air per hour when going at 4,500 revolutions per minute, with iron knee-pipe for connecting with air-vault, or direct to underground pipe . .	9	15	0
4 dampers, with rod, at 14s. each	2	16	0
100 feet earthenware piping, at 5d. per foot . .	2	1	8
Thermometer, and 8 tubes for the same	2	5	0
	£16	17	8

Or about 3s. 6d. per ton of hay, exclusive of the shed.

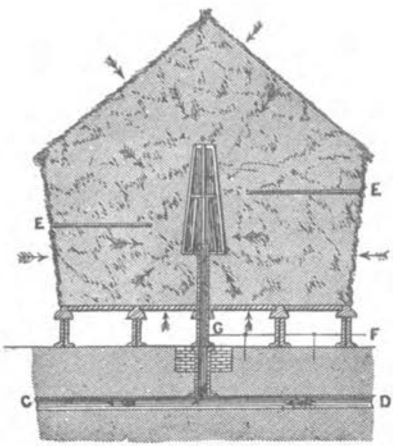


Fig. 72.

A. Cavity in centre of stack.
B. Hollow centre pillar of rick-stand.
C. Underground pipe leading from stackyard to exhaust-fan.
D. Underground pipe leading to other stacks.
EE. Tubes for inserting thermometer into stack to ascertain heat.
F. Handle outside of stack to open or close damper.
G. Damper.

Fig. 72 shows an arrangement for a series of stacks built upon T. Pearson and Co.'s Vermin-proof Rick Stands, with underground piping.

The engraving (Fig. 73) shows T. Pearson and Co.'s Hand-power Fan, operating upon a stack built upon the ground. In this case a wooden shute or pipe, B, is laid on the ground, one end terminating in the cavity, A, and the other at outside of the stack. The fan is connected with the shute by an iron knee-pipe, and can be attached or detached to or from the pipe in a few minutes, and carried from stack to stack easily by two men, and is thus available for cooling successively any number of stacks.

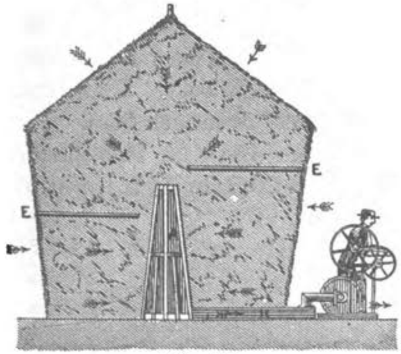


Fig. 73.

The cost of this mode of applying Neilson's system will be as follows:—

	£	s.	d.
Exhaust-fan, with knee-pipe	9	15	0
Wooden shute, 10 feet long, for connecting boss with fan, for each rick	0	10	0
2 iron tubes and thermometer	0	15	0
	£11	0	0

As the fan is available for any number of ricks, the outlay is proportionately smaller the greater the number of ricks operated on.

Fig. 74 is an illustration of Root's Blower or Exhauster, ventilating hay, straw, grain, and other ricks. It is being worked in connection with barn machinery by one of Bailey's water motors already mentioned. The blower is made in sizes capable of exhausting from 40 to 1,000 cubic feet of air per minute, and at a cost complete, without the motor power, of from £5 to £20.

Mr. Gibbs's system of harvesting is to dry the hay or corn sheaves before going into the stack. His plan is

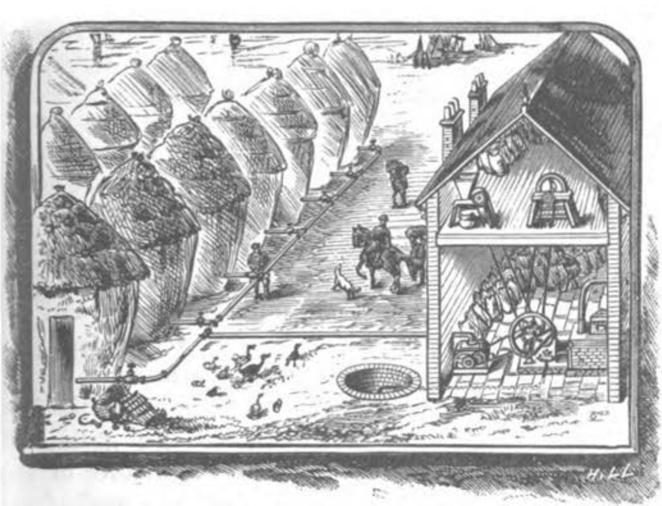


Fig. 74.—Root's Patent Extractor.

to employ hot air, which is forced into a perforated cylinder over which the wet grass or sheaves are passed in the drying chamber, until the forage is dry enough for the stack. Mr. Gibbs has also invented a hot-air cylinder for drying grain, tea, &c.; and various inventions of a similar kind have lately been patented by others for the purpose of drying and purifying damaged grain.

CHAPTER XV.

RICK-YARD APPLIANCES.

Rick Stands. — Fig. 75 shows one of the patent wrought-iron Vermin-proof Rick-stands, manufactured by Messrs. Bayliss, Jones, and Bayliss. They are made oblong or rectangular, as well as circular.

The use of these rick-stands effects an immense saving to farmers by preserving grain from damp and vermin, and by giving perfect ventilation. In many cases the expense of the outlay is almost covered the first year by the saving of grain, and the imperishable nature of the stands prevents the need of renewing during a lifetime if a little care is taken to paint them every second or third season.

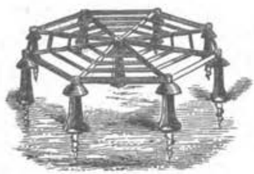


Fig. 75.

The oblong rick-stand is suitable for wheat, oats, barley, or hay. It is made in the same way as the circular stand, no screw, bolt, or pin being required; and, like the circular stand, can be very quickly erected or taken down by a farm labourer. One advantage peculiar to this stand, however, is that it can be shortened 6 ft. at a time, as the grain is removed, so as to allow carts to get close up to the remaining portion of the rick. These oblong stands are also somewhat lower in price than the circular stands, and are better adapted for use under sheds.

Stacking Machines are now much used, and are of two kinds: (1) the "Horse Pitchfork," which takes the hay from the waggon and deposits it on the rick; and (2) the "Straw Elevator," driven in connection with the threshing-machine, or separately by a small horse-gear. In the latter machine the straw, &c., is thrown into the hopper of the elevator, whence it is raised to the top of the stack by means of endless chain-rakers.

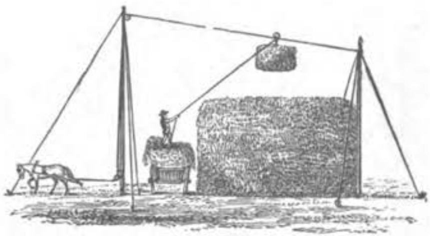


Fig. 76.

Fig. 76 shows Walker's Improved Horse Pitchfork, by Coleman and Morton, and the mode of working it.

Its value in saving labour and expediting the stacking of hay can scarcely be overrated; in addition to which it has been extensively used for stacking barley and straw.

The fork is made almost entirely of steel, weighs only 8 lbs., and will take up as much hay at a single forkful as a horse can raise. It is very simple, not liable to get out of order, and can be managed by a boy. It will raise the hay to any required elevation and deposit it on any part of the stack.

The directions for working it are as follows:—

Fix two rick poles, one considerably higher than the other, firmly in the ground (and well stayed by guy ropes), the shorter one at the end of the stack, the other at a sufficient distance to allow of the waggon being unloaded midway between the two.

Fix one pulley at the top, the other near the bottom of the high pole. The rope, which should be 7-8ths of an inch in diameter, must pass through these two pulleys, then through the swivel hook pulley, which is to carry the fork and stretch across to the other pole, on which it must be made fast, so that when tight it inclines toward the stack.

Fig. 76*a*. Fig. 76*b*.

A whipple-tree, for a trace-horse, must be attached to the other end of the rope.

In unloading the hay the sliding-pulley is drawn down to the top of the load; the man using the fork presses it into the hay as far as possible by the lever; the lever is then brought into a perpendicular position, so that the point of the fork forms a right angle (see Fig. 76*b*); the fork is hooked to the pulley, and, the horse being started, the hay is raised sufficiently high for the pulley to slide along the rope to the desired spot over the stack.

While the fork is thus elevated, the hand-cord attached to the small eccentric lever must be pulled by the man in the waggon, when the hay will be instantly discharged upon the stack (see Fig. 76*a*).

In unloading, the fork should be inserted alternately in the back and front part of the load, the best method of arranging which will be determined by a little experience.

Clay's Patent Piercing Stack Thermometer.—This (Fig. 77) is a simple instrument for testing the temperature of stacks, whether of hay or corn. It is only requisite to thrust the instrument into the side of the stack, anywhere, and allow it to remain there a short time. The thermometer, made specially for this purpose, being enclosed in an iron tube, readily answers to the temperature of the stack, and on being withdrawn the point at which the quicksilver stands is easily seen through the long sight-hole, as shown in the engraving.

A red line is marked at 170°, at which point the heat becomes dangerous, and the stack may soon take fire, the actual point of ignition being about 200°. This thermometer is not only useful to those farmers who wish to adopt the new fan system of drying ricks, but to all those who desire to have a safe record of the temperature of stacks made in the usual way.

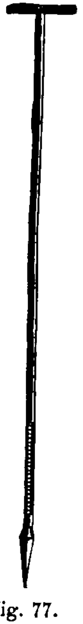


Fig. 77.

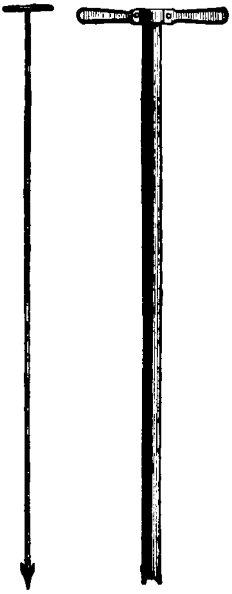


Fig. 78.

The price of the instrument, with improved bayonet point and key, and with registering thermometer in brass case, is 27s. 6d.

Clay's Patent Stack Tester.—This (Fig. 78) is a handy instrument for extracting samples of hay or corn from the outside to the centre of stacks, giving a much better idea of the bulk in case of a haystack than by merely hooking a small piece out here and there with a trial iron; whilst the taking of a fair sample of corn from the heart of the stack is a very difficult matter, which this little instrument entirely overcomes.

The instrument is made of a fine cold-drawn steel tube, with cutters at one end and a cross-handle at the other. A hole 2 in. in diameter is cut into the stack, by boring the tube into it, and the samples are extracted at the outer end, as the work goes on, with the small barbed rod used in connection with the tube.

This tube may be usefully employed for cutting holes into large haystacks for the purpose of inserting the thermometer-stick, when such stacks have become too solid, near the ground, for thrusting the thermometer into them by force of hand.

The price of this stack-tester, 7 ft. long, 2 in. in diameter, with cross handle and extracting rod complete, is about 30s.

Hay and Straw Compressors.— Various kinds of forage-presses are now in use for baling and trussing hay and straw. By this means these bulky crops can be so compressed that five or six tons can be put upon a truck instead of two tons as formerly, and thereby a great saving in railway carriage is effected. Less manual labour is also required than by the old method of hand-trussing; and the machine is very much more expeditious.

Hay-Knife.—The common hay-knife consists of a straight blade set at right angles to a short wooden handle. It is used for cutting hay or straw when consolidated in the stack. An improved hay-knife is shown in Fig. 79. This instrument has a serrated edge, and is double handled. It was awarded "First Order of Merit" at Melbourne Exhibition in 1880, and

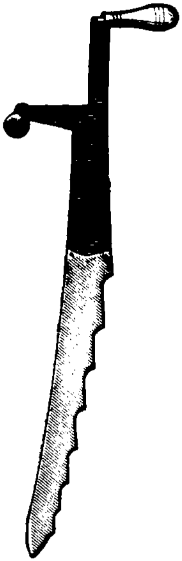


Fig. 79.

was also awarded the *first premium* at the International Exhibition in Philadelphia in 1876. It is an American invention, known as Weymouth's Patent, and is the best knife in use to cut fine feed from bale, to cut down mow or stack, or for cutting ensilage from the silo.

CHAPTER XVI.

APPLIANCES USED IN FEEDING STOCK.

Corn-Bins.—Stable bins should be large enough to contain a week's supply of corn for the number of horses to be fed by one man. For one horse, a 4-bushel bin will be large enough, but for a pair of horses the bin should have a capacity equal to 8 to 12 bush. Corn-bins are now mostly made of stout rivetted wrought iron, of which we give two examples (Figs. 80 and 81), by the St. Pancras Ironwork Company.

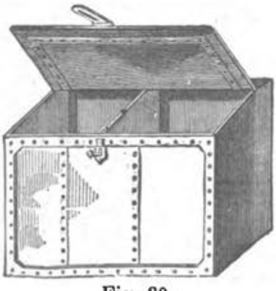


Fig. 80.

Fig. 81.

They are made of various shapes to suit different positions in the stable or hay-loft.

Feed-Sifters and Measures.—Figs. 82 and 83 show a sieve used for taking the dust out of corn and chaff before giving to the horses. Feed measures are usually made in ½ quartern, quartern, and ½ peck sizes.

Fig. 82.

Fig 83.

Corn-Shoot and Meter.—This useful article (Fig. 84) is supplied by the St. Pancras Company. The meter is formed in the lower end of the shoot, and is so constructed that only one feed can be taken out at a time. It works easily and rapidly. The shoot may also be had with plain slides without the lever handle. Chaff-shoots may be had on a similar plan.

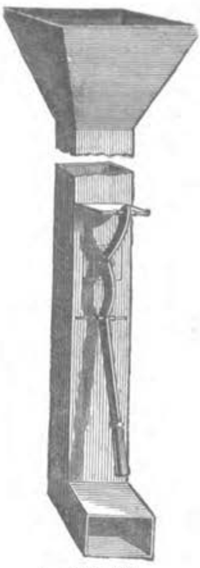


Fig. 84.

Automatic Horse-Feeder.—A very ingenious apparatus of this kind has been patented by J. P. Milbourne, of Manchester. It is intended to deliver food to horses at any hour in the day or night, thus obviating the consequences of unpunctuality or forgetfulness on the part of the attendant, and overcoming the evil of horses being turned out to work with an empty or nearly empty stomach. It consists of a shoot or spout, which is fixed over the manger, and some mechanism of which a clock forms part. The food is put into the shoot over night, and the clock can be set for any hour, on the principle of an alarum, and at the desired time half the food is shot into the manger, the rest falling half an hour later. By a modification, water can be supplied at the same time. One apparatus can be used for any number of horses, provided they are stabled in one building or in contiguous buildings, and it is equally applicable of course to cattle-feeding. It will be found valuable in busy seasons, and in cases where horses come home late at night, and do not require all their food or water to be given to them imme-

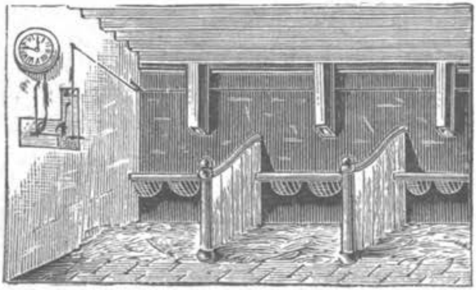


Fig. 85.

diately. Horsekeepers are thus saved from sitting up late at night, or staying with their horses a long time after the day's work is over, as they do on farms in some parts of the country. It must prove especially economical where a large number of horses are kept, as at the desired time they can all have their food in the manger at the same moment, and thus avoid a great amount of neighing, pawing, and uneasiness. In stables not having a loft overhead, each manger is divided into two parts by a partition, one-half being covered by a lid. The food is placed in the manger, the lids closed, and at the desired time they are opened simultaneously, and the horses begin to feed.

Pig-Troughs.—For the pig-sty, the oscillating trough is superior to any other. It is usually made 6 ft. long and 4 ft. high, with cast-iron ends, prepared either for building in a wall or fixing to a railing. The trough has a circular bottom with divisions across, and has an oscillating flap or door suspended from the upper frame, which excludes the pigs from the trough entirely whilst the food is being placed in it.

For open-yard feeding, the improved circular trough, with hopper, is the best. It admits of food being poured into it while the pigs are feeding.

Cattle-Cribs.—The galvanized Cattle-crib (Fig. 86) manufactured by Messrs. Jones and Bayliss, is a great improvement on the old wooden ones, and being made entirely of wrought iron, are very strong and durable. They are usually made from 3½ to 4 ft. square and

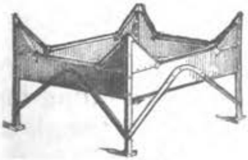


Fig. 86.

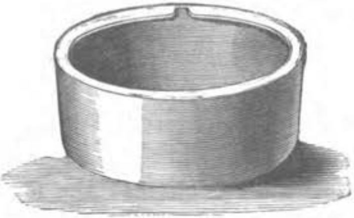


Fig. 87.

9 inches deep; and at least four full-grown bullocks can feed at one and the same time from each crib. A great advantage of these cribs is that they are equally suitable for feeding cake, meal, roots, chaff, or uncut fodder. They are also as serviceable in the pasture field as in the cattle-yard.

The round-lip Pans (Fig. 87), manufactured by

Messrs. Ransomes, Head, and Jefferies, are particularly to be recommended for feeding cake, &c., to cattle on the pastures. Being made of cast iron, the pans are so weighty as not to be easily upset, and the lip prevents waste of food otherwise. One pan is allowed to each bullock, so that each animal can get its full share of the food. The pans are made in sizes varying from 10 to 20 in. in diameter; and to contain from 1 to 9 gals. of either food or water.

Sheep-Racks.—This engraving (Fig. 88) represents a portable wrought-iron Sheep-rack, by Hill and Smith, well worth the attention of farmers. It is on four

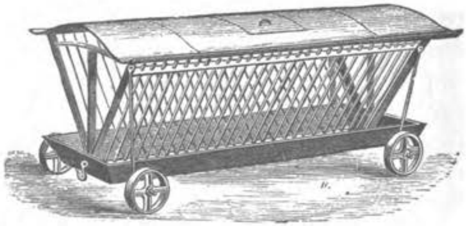


Fig. 88.

wheels; is covered with an iron roof, guttered to carry off the rain at the ends; and is fitted with a lifting-top for the reception of the fodder. It has a trough at bottom of wrought iron, 2 ft. wide, extending the whole length of the rack, which prevents waste of hay, and catches the hay-seed from the rack, and is also useful for feeding sheep with corn, oil-cake, salt, or cut fodder. It is capable of feeding upwards of a score of sheep at once, is very strongly made, to be drawn by one horse, and will travel without injury on the road.

Sheep-Troughs.—Wrought-iron troughs are now fast superseding wood ones for sheep-feeding. Fig. 89

shows one of Hill and Smith's iron Sheep-troughs on wheels, so as to be readily drawn about by a lad. It can be used for food or for water as required. It is

Fig. 89.

9 feet long, and is made with a rod over the centre, from end to end, to prevent sheep from jumping over or getting into it, and it is so firm that it will not upset.

Calf-Feeder.—Tucker's Calf-feeder, shown in Fig. 90, is well calculated to facilitate the feeding of calves when brought up by hand. It is simply a tin vessel, holding a few quarts of milk, with a gutta-percha teat secured on the lid, and the end of the teat-tube almost touching the bottom of the pail. The teat has a valve, through which the fluid within is drawn by a slight pressure of the calf's jaws. The artificial suckler is far preferable to feeding young calves with milk in open pails. It is less wasteful to begin with; and the slower process also of drawing out the milk in the natural way by suction, instead of drinking it by mouthfuls, is more beneficial.

These feeders are also used for colts, which take to them readily; and in the event of a mare dying, or being needed for work, they will be found invaluable. In the latter case the dangerous effects of sucking the mare when overheated by labour are avoided.

Lamb-Feeder.—The Lamb-feeder (Fig. 91) is on the same principle as the calf-feeder. It is, however, fitted with six or seven teats, so that six or seven animals can feed from it at one and the same time. It has also

Fig. 90.

Fig. 91.

been successfully used in the rearing of pigs. Both these feeders are supplied by the Aylesbury Dairy Company.

CHAPTER XVII.

DAIRY APPLIANCES.

Cow-Milkers.—Over fifty patents have been obtained for cow-milking machines, about fifteen in England and forty in America.

These machines have been divided into three classes :—

> Tube-milkers, or tappers;
> Sucking-machines; and
> Mechanical hand-milkers, or squeezers and strippers.

Some machines are a combination of these classes. As yet, however, no one machine can be considered a success. Were it otherwise, these machines would speedily come into use. Various inventions have, no doubt, obtained a partial success in extracting milk from the udder of the cow; but until their action is at least as thorough and complete as hand-milking, they are practically useless. Every cow-keeper knows that any milking which is not thorough would soon ruin his cows as profitable yielders of milk; so that, important though a saving of the labour of milking is, it must not be purchased by any sacrifice of efficiency.

In the sucking machines, the milk is drawn from the teats precisely after the manner of the young calf. The calf draws a quantity of milk from the cow and then stops to swallow. So with the machine; as the handles are pressed together, the milk flows into the pump; as they return, it passes out through the valve into the pail.

Milk-Testers.—The instruments used for testing milk are the thermometer, the cream-gauge, the lactometer, the lactoscope, the pioscope, and the lactobutrometer. The value of milk-testers has, however, been but little appreciated by British dairy farmers in the past.

"In all those countries with which British dairy farmers have to compete, the farmer would be laughed at who would attempt the making of either cheese or butter without testing apparatus. A dairymaid would be surprised if you proposed to make butter or cheese without a thermometer, and even a complete set of testing-apparatus, to enable her to go to work scientifically and successfully." It is therefore satisfactory to note "that dairy farmers and town dairymen in England are becoming alive to their position in competition with the Continent of Europe, the United States of America, and our colonies."

The proportion of cream in any sample of milk can be determined by the cream-gauge, which is simply a glass tube, about 5 inches long, graduated from zero downwards. The milk to be examined is poured into this tube up to zero, and allowed to stand about twelve hours, at the end of which time the cream will have risen to the top, and its percentage may be read off. In good milk there should be at least ten per cent. of cream.

This instrument, although very useful to those who sell cream, is not reliable in detecting the adulteration of milk.

The lactometer, or hydrometer for milk, indicates the specific gravity of milk, that is, the relative difference in weight between milk and water. The specific gravity of water is 1,000, and that of milk may be taken to average about 1,030.

The specific gravity of milk varies, however, not merely with the amount of water it contains, but with the amount of butter fat in its composition, and for this reason the lactometer used alone is of little or no practical value. As cream is lighter than milk, and of nearly the same specific gravity as water, it follows that when milk is very rich or contains a large proportion of butter fat, its specific gravity is less than the ordinary standard, and if tested by the lactometer alone might give the idea that it had been watered. A cream gauge should therefore always be used in connection with the lactometer, in order to test the amount of cream or butter fat in the milk.

The best instrument for testing the value of milk hitherto invented is the so-called lactoscope. This shows, with considerable accuracy, the percentage of fat; and fat being the most valuable constituent of milk forms a safe gauge as to the purity and value of the milk.

The action of this instrument depends upon the fact that the opacity of milk is chiefly caused by the globules of cream. So that when water is added to milk until we can see through a certain proportion of it, we are able to do so because we separate the cream globules to that extent that light can pass through between them with a certain degree of clearness. Then, if we measure the amount of water added, we have quite an accurate gauge for comparing different samples of milk.

The lactoscope, however, as well as the pioscope and the lactobutrometer, is less simple than the cream gauge and the lactometer, and therefore less suitable for ordinary use in the dairy.

Refrigerator.—Lawrence's Capillary Refrigerator, of which we give an illustration in Fig. 92, is one of the most profitable appliances for the dairy.

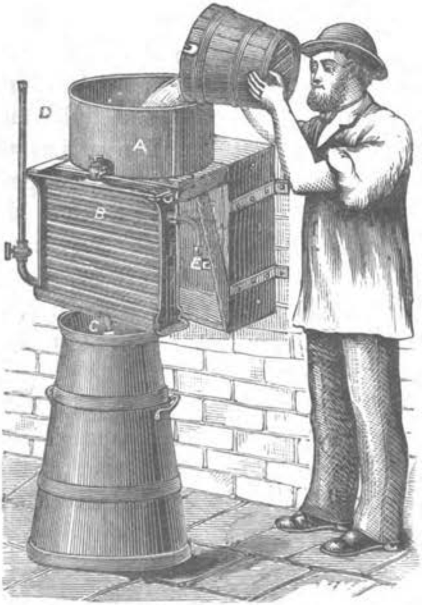


Fig. 92.

A, warm-milk receiver; B, refrigerator; C, milk exit; D, water inlet; E, water exit.

By the aid of these refrigerators, the milk intended for transit, or for the making of butter or cheese, may be cooled as soon as it leaves the cow, and before any injurious change can possibly have taken place. It is now well known that milk is preserved in proportion to the rapidity with which it is cooled. The explanation of this is that, when milk is suddenly cooled, the floating germs, which are the cause of decomposition, are destroyed, and the milk is consequently preserved; whereas if cooled by slow degrees, living infusoria will still be found in it.

By passing warm water through the refrigerator, instead of cold, the temperature of the milk may readily be raised to any degree required, which, in cold weather, is a great advantage in cheese-making.

The refrigerators are made in sizes capable of dealing with from 80 to 250 gallons of milk per hour.

Milk-Strainers.—The milk as it comes from the cow-house requires to be put through a strainer to insure it being free from straws, &c. The strainers in common use are shaped like a cup or bowl, and have fine brass wire sieve bottoms, in addition to which a straining cloth is sometimes used.

Milk-Pans.—For shallow setting the pans now most recommended are of the pattern shown in Fig. 93. They are enamelled white inside, black outside; cool, sweet—being readily cleansed—and presenting a large cream surface. Milk pans may be had in white porcelain or in tin. The latter are blocked out of one piece of steel, and are without seam or joints.

Milk-Stands.—The old plan of setting the milk-pan upon shelves around the dairy walls is being fast abandoned in favour of portable disc stands, after the patterns shown in Fig. 93. These are not only portable but revolving disc stands. They utilise space, as they can be placed in line or in square; while the revolving discs or tables allow of skimming each pan without moving from one position.

Being portable, they can be placed in the most desirable position for ventilation, and for thorough cleansing of the milk-house walls, which fixed shelves do not admit of.

Deep Setting.—The deep-setting system is coming into general favour, and is fast superseding the old shallow-pan method of cream-raising. The theory that shallow setting promotes quick rising is exploded, while it is now well known that the souring of milk is due to the development of germs which are always floating in the atmosphere, and are sown, like seed, to flourish when they fall on suitable soil. Of such a soil the shallow pan exposes a very large area, while the deep pans expose but little.

It is claimed by the advocates of the deep-setting system that warm milk suddenly immersed in cold or

Fig. 93.

iced water, throws up sweeter cream in larger quantities, and in less time, than when set in shallow pans. It also requires less space, and the butter made from it is said to keep better.

The Swartz System.—The "Swartz" Pan, so named after its inventor, was the first deep pan introduced into England. These pans are placed side by side in a trough or cistern filled with cold water (Fig. 94), and through which, if convenient, a slight stream is allowed to flow. The trough, with inlet and outlet taps, &c., to hold water for immersing the pans, may be constructed of wood, stone, slate, or brick, either above ground or in the floor of the dairy.

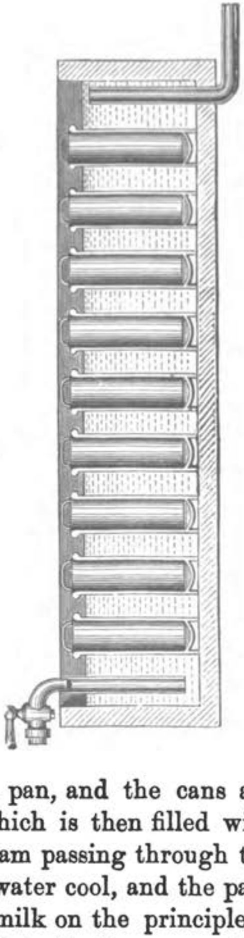


Fig. 94.

Fig. 94 shows a longitudinal section, and explains the manner in which the pans and taps are arranged. The "Swartz" pans, it will be observed, are narrow and oval in shape. They are made of the best tin-plate, with tinned iron bottom hoops and handles, and usually of a size to contain 40 qts. of milk each.

Cooley Creamers.—Among American dairymen Cooley's Portable Creamery is much in favour for deep setting. Under the "Cooley" system the milk is strained into cans 20 in. deep and 8 in. in diameter, each covered with a small inverted pan, and the cans are all packed in a closed box, which is then filled with cold water, a constant cold stream passing through the box, or ice is used to keep the water cool, and the pans keeping the water out of the milk on the principle of the diving bell. It is found that all the cream rises within twelve hours, and owing to the temperature of the water being kept below 50°, the skimmed milk is perfectly sweet, and is used for cheese-making and other purposes.

Fig. 95 is a tranverse section of the Cooley Creamery. The animal odours and gases are more effectually disposed of by this process than by any other, for the reason that the covers do not fit closely down on the cans, thus securing a free circulation from the milk into the water through the air confined under the cover; at the same time the water most effectually seals the milk from any contact with the atmosphere, and as the milk when placed in the cans is at a temperature of from 80° to 90°, and the water from 45° to 55°, the natural effect is for the odours and gases of the milk to rush into the water and be immediately absorbed by it.

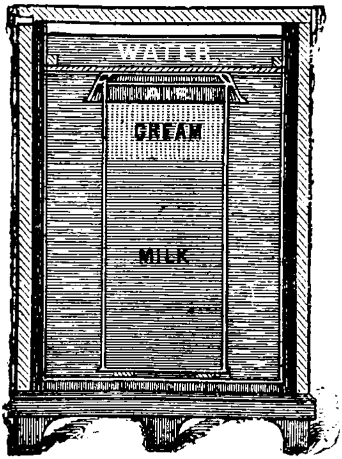


Fig. 95.

To determine the size of a creamer required for a dairy of a given number of cows, the following calculation will be found approximately correct, reckoning the capacity of the cans at 16 qts. each.

For a dairy of	1 to 3 cows,	1 creamer with	1 can,	16 quarts.	
,,	4 to 6	,, ,,	2 cans,	32	,,
,,	6 to 9	,, ,,	3 ,,	48	,,
,,	9 to 12	,, ,,	4 ,,	64	,,
,,	12 to 18	,, ,,	6 ,,	96	,,

For a dairy of	18 to 24 cows,	1 creamer with	8 cans,	128 quarts.
,,	24 to 30	,,	,,	10 ,,	160 ,,
,,	30 to 36	,,	,,	12 ,,	192 ,,

Cream-Separators.—The separation of milk from cream, which is slowly effected by gravitation in the pan-setting systems, is brought about instantaneously by means of the Centrifugal Cream-Separator, which is a machine of comparatively recent introduction. It consists, in its simplest form, of a milk drum or cylinder, which is made to revolve at a very high speed, and in the process the milk being poured in, the light cream globules gather around the axis, and are drawn off separately, whilst the heavier milk globules are thrown outwards towards the circumference, and discharged by another pipe.

This ready method of separating the cream is of great importance where sweet cream butter is wanted, and still more so where the skim-milk is sold, as it can then be sent off quite fresh, and will, consequently, bring a better price. It has been conclusively proved that the machine extracts more cream from the milk than can be raised by the open-pan system. It is said that the machine-extracted cream also yields more butter.

In an extensive series of experiments tried in a Danish dairy of 200 cows, where the three systems of cream-separating were tested, viz., the centrifugal machine, the Swartz system of deep cans set in cold water or ice, and the shallow-pan system, the results of some two years' working were altogether in favour of the machine. The average proportion of cream left in the milk was only ·35 per cent. of the centrifugal system, and occasionally it was as low as ·15, while it was ·62 per cent. with the Swartz cans, and ·68 per cent. with the shallow pans. It was stated as the result of the whole set of experiments that the centrifugal system gave over 8 per cent. more butter from the same quantity of milk set in ice on the Swartz system, and over 10 per cent. more than the shallow-pan system. The best evidence in favour of the machine, however, is, that it can extract cream from milk that has been previously skimmed on the old method.

It has been observed in different experiments with the separator that the skim-milk makes a poorer quality of cheese than ordinary skim-milk. This is, of course, due, in a great measure at least, to more of the cream having been removed. Complaints are occasionally made that the skim-milk from the separator does not keep sweet so long as ordinary skim-milk, but this can easily be remedied by scalding the skim-milk when it is to be kept for any length of time. And, indeed, in order to obtain the best results, milk should be about 90° Fahr. when run through the machine.

A great many varieties of centrifugal cream-separators have been brought out, but only two of them, viz. the Swedish or Laval Separator, and the Danish Separator, have as yet been favourably reported on in this country.

The Laval Separator, which is perhaps the best-known machine, does its work well, and is a cheap article, costing only £32, and separating 60 galls. of fresh milk per hour; but the difficulty is, it does not seem possible to enlarge or reduce it in size. Its revolutions are also very great, and the power required to drive it considerable.

Fig. 96 is a section of this machine. The milk as it comes from the cow is placed in a milk-can, and delivered by means of an ordinary tap into the funnel *a*, and through the small tube *g*, connected with the funnel, into the rotating vessel A, which runs at a

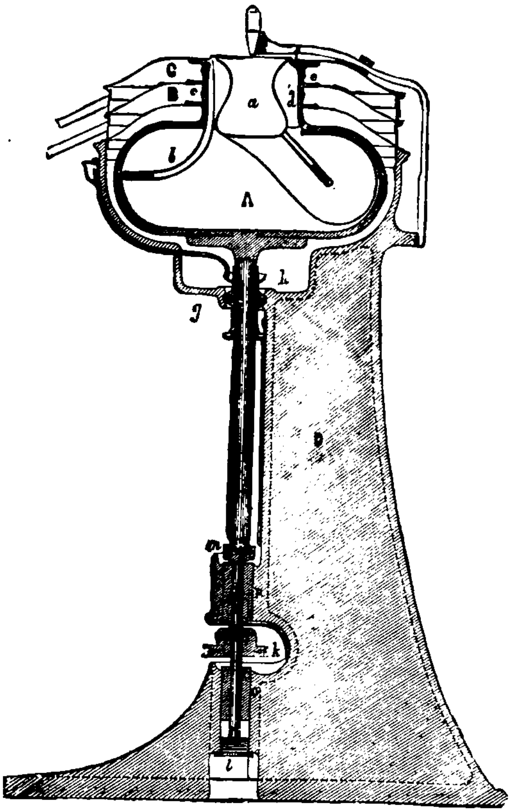


Fig. 96.

velocity of 6,000 or 7,000 revolutions per minute. To the bottom of the funnel is soldered a thin wing, which forces the milk to follow the rotation of the vessel.

As soon as the fresh milk enters the rotating vessel, an instantaneous separation takes place. The heavier portion, or the skim-milk, is thrown towards the circumference of the vessel and forced up the bent tube *b*, whence it is delivered through the aperture *c* into the lower of two tin trays or covers B, which is provided with an outlet pipe. The cream remains nearer the centre, rises around the outside of the funnel *a*, and through a small hole in the cylindrical upper part of the rotating bowl it delivers itself at *e* into the upper cover C, whence it is discharged through an outlet pipe.

The opening *e* is regulated by means of a small screw *f*. In making this hole narrower the cream obtained will be thicker.

The Danish Separator (Fig. 97) is made in two or

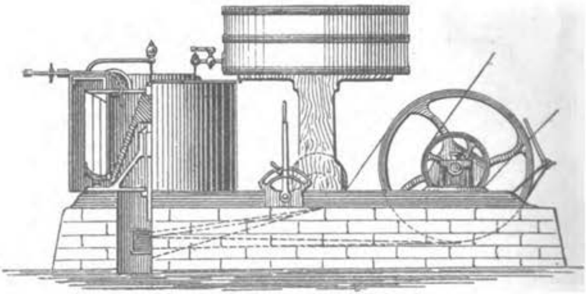


Fig. 97.

more sizes. It consists of a horizontal drum, in the centre of which is a metal cone, and within this the driving shaft.

A section of the machine is shown at Fig. 98. The skim-milk escapes at B, and is drawn off by beak and tube C and D. The cream when gathered in sufficient thickness, is drawn off by the beak E, and tube F.

If thin cream be required the cream is drawn off continuously, but if thick cream be required the beak E is put into work when desired, that is to say, when the wall of cream is seen to be of sufficient thickness. This power of regulating the quality of the cream

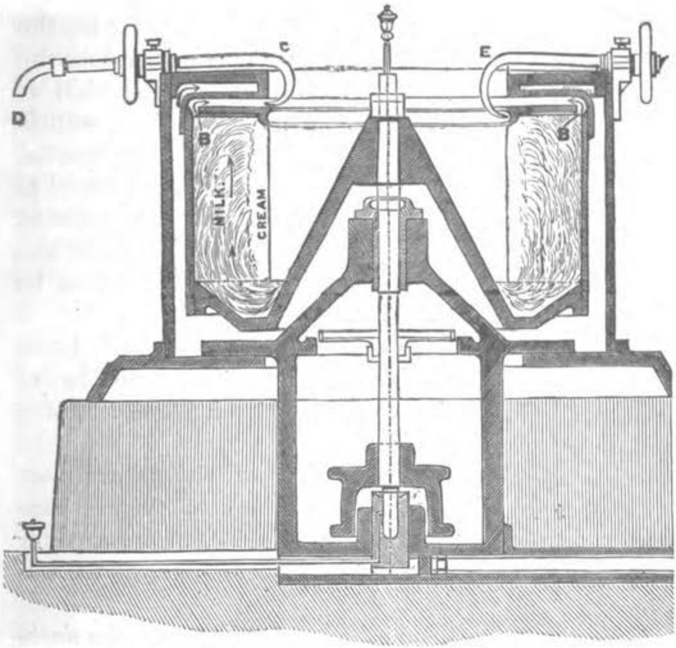


Fig. 98.

is one of the most valuable points in the Danish Separator.

The latest of these machines is fitted with a regulator by which the quantity of cream to be taken off is regulated exactly. "Thus, where cheese-making is combined with butter-making, it may be advisable to leave the skim-milk rich or to sell it rich. To this end the milk as it leaves the vat above pours through a little vessel, in the two corners of which are tubes which screw down into the feeder of the drum. These permit a larger or smaller quantity of milk to escape into the separator at will, the quantities being marked on the rod. When the normal quantity is let in, the cream is all taken; if more, then the skimmer does the same work with a larger volume of milk, so that it naturally takes less cream. Another improvement is an arrangement by which the revolutions are counted per minute, and this is very exact; a cogged wheel is driven by the revolving shaft, this moving a figure at each revolution, and so on, until, by the aid of the watch, hundreds of thousands of revolutions can be accurately timed."

The Danish machine only works at a velocity of 1,800 to 2,000 revolutions per minute. It is capable of separating 120 galls. of milk per hour. The cost of a machine to do this is about £80.

Churns.—An immense variety of churns are now offered by manufacturers, and new forms are constantly being introduced, but the best of them differ but slightly in principle from one or other of the old churns.

The simplest and oldest form of churn is the *dash-churn.* This consists of a long narrow tub, tapering upwards to allow of tightening by hoops. It has a lid, and in that a small central aperture, through which works a staff or handle, having on the bottom of it, inside the cylinder, a round disc of wood with a number of holes cut in it. The diameter of this disc or piston, is something less than the upper diameter of the cylinder. The simple motion perpendicularly of the handle upwards and downwards works the piston at the bottom, through the cream, and agitates it sufficiently to cause it to throw up the butter in lumps. This churn may be worked by hand or power, but it is less effective than most of the other churns we have to describe, and is now in fact seldom used.

Fig. 99.

Hathaway's Improved Barrel Churn (Fig. 99) is a very serviceable one. It is a plain barrel or cylinder, having a hole in one side, through which the cream is admitted and the butter extracted. Over this hole is a plate of metal or wood, which can be screwed down, a piece of cloth being first placed between the parts. In the centre of each end of the barrel are securely and accurately fixed two gudgeons or spindles. These are placed in proper bearings set upon a strong frame, and on one end of the gudgeons, or both, are placed winches, by which the barrel is made to revolve. In the interior of it, parallel with its axis, and secured to it, are pieces of board radiating from its centre. These agitate the milk as the barrel is turned.

The chief defects of this churn are a too great tendency to carry the milk round with the barrel, and the difficulty of getting at the interior to properly cleanse it after churning.

Another barrel churn is made in which the barrel remains stationary, and a central shaft, upon which the dashers are fixed, is made to revolve. The operation is much the same as in the other barrel churn, except that in one case the milk is worked against the dashers, while in the other the dasher is worked against the milk.

In the Box Churn the dashers usually revolve on the spindle; but, in cases, the churn revolves, as with Hathaway's barrel churn, the only difference here being that the box churn is square or rectangular in form.

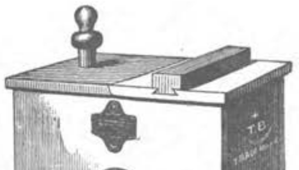


Fig. 100.

Fig. 100 represents Bradford's "Declivity" Box Churn.

One-half the cover of this churn is a fixture, and therefore effectually prevents back slop or leakage; while the movable half affords ample space for taking out the dash and cleaning the interior.

The two wood-set screws are to tilt the churn when either an unusually small or an exceptionally large quantity of cream has to be churned. In the former case the cream is collected at the lowest point of the churn and gets the full benefit of the dash, and in the latter case the capacity of the churn is largely increased, as the cream will not leak at the end of the spindle even with a larger quantity—say, one-fourth—than the churn will hold on the level.

An essential difference in the various box churns is in the shape of the dasher, one form of which is shown in Fig. 101.

For a small dairy of one or two cows the box churn

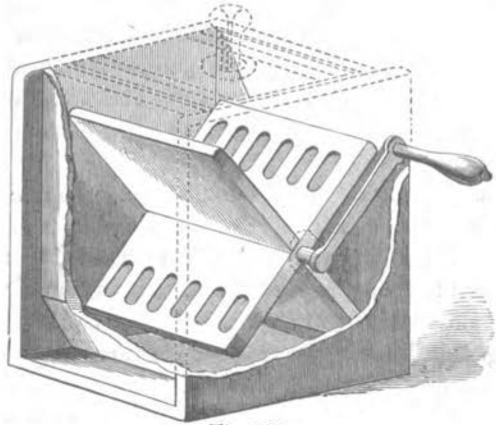


Fig. 101.

is as good as any, and can be easily takèn to pieces and scalded.

All the recent improvements in churns are embodied in Bradford's new patent "Diaphragm" Churn (Fig. 102). It is made in various sizes, suitable either for hand, horse, or steam-power.

Fig. 102.

The construction of this churn is very simple—octagonal, with unequal sides, the interior perfectly plain but having a moveable screen with partitions so arranged that as the butter forms the globules have a tendency to aggregate, without risk of bruising from violent contact. When the result is obtained the diaphragm is moved, and the butter-milk drawn off. The churn is fitted with two diaphragm divisions, one for churning cream, the other, or converging current division, for churning milk.

Various other churns, too numerous for even a brief description, are still largely in use. Amongst these are the Midfeather, the Eccentric, and the Cotswing churns, the names of which are suggestive of their differences.

For a large dairy the "diaphragm" churn is the best now in the market.

Never allow water, whether hot or cold, to remain in a churn; after using, cleanse the churn with a dairy brush, and then simply rinse with boiling water, leaving the lid off so that the churn may become sweet and dry as soon as possible.

Mechanical Butter-Workers.—The butter-worker is one of the most necessary implements in the dairy. It is simply a matter of impossibility to work out all the whey from the butter by hand kneading, and the few particles not expelled act as a ferment, and prove the fertile cause of butter so soon turning sour or contracting a cheesy flavour.

These machines work the butter perfectly, and expel every particle of whey without the hands having to touch it at all, and butter so made commands a better price. No dairymaid having once used the butter-worker ever dreams of doing or trying to do the same work by hand. In all the best butter dairies the produce is now turned out without ever once having been touched by the hand.

For very small dairies the Board-and-Roller Butter-worker (Fig. 103) will be very suitable. The open end of the board rests upon a table or other convenient support.

For medium-sized dairies, Bradford's Improved

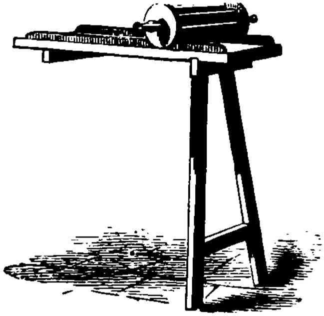


Fig. 103.

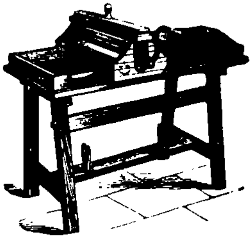


Fig. 104.

"Turnover" Combined Butter-Worker and Dairy Table (Fig. 104) is recommended. This is a convenient and powerful butter-worker. The table top folds up

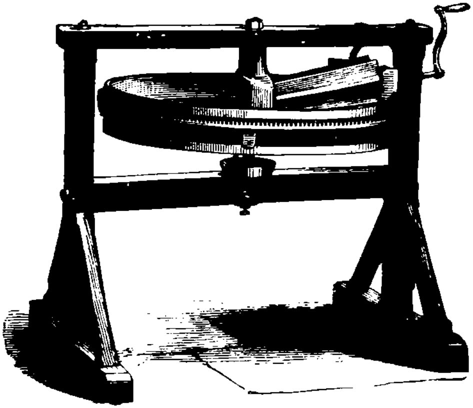


Fig. 105.

and covers the butter-worker, and when this is lifted off, there remains a most convenient dairy table for general purposes.

Fig. 105 gives a view of Bradford's "Springfield" Prize Butter-Worker. It differs from the "Embree" butter-worker in having its revolving table hollowed towards the centre, which allows the whey to fall freely through an opening specially provided in the centre, the butter being worked *upwards* by a differential motion of the fluted roller towards the outer rim, which effects a more efficient working of the butter, and with greater certainty, in less time.

Larger sizes of this machine are made to suit horse or steam-power.

Butter-Presses.—It frequently happens that the market value of really good butter is depreciated by want of skill and taste in the making of it up in sharp, well-defined pounds or half-pounds. To simplify and insure uniformity in this process, a simple machine, on the principle of a brick-press, has been brought into use, and will in time entirely take the place of the old wooden hands or butter-beaters. With these admirable presses, even in the hands of an inexperienced person, this desirable market form is secured with mechanical certainty. These presses are made with round or rectangular prints carved to any design. Fig. 106 is an engraving of a butter-press supplied by the Aylesbury Dairy Company.

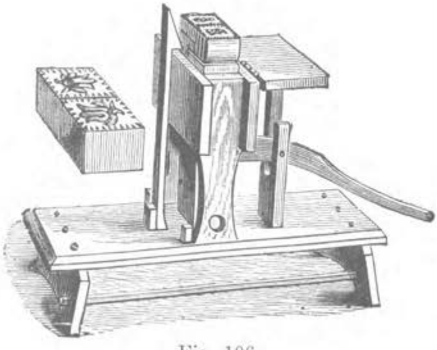


Fig. 106.

Cheese-Making Apparatus.—Considerable improvements have been made within the last few years in the various implements and utensils used in cheese dairies. These consist of milk-vats, curd-mills, vat-sieves, curd-cutters, curd-shovels, draining-racks, and cheese-presses, &c., &c.

Milk-Vats.—One of the most recent changes in cheese-making apparatus is the use of square or long vats in place of the old-fashioned round vats. The square vats admit of greater facility in cutting up the curd. These vats have now been exhibited for two or three

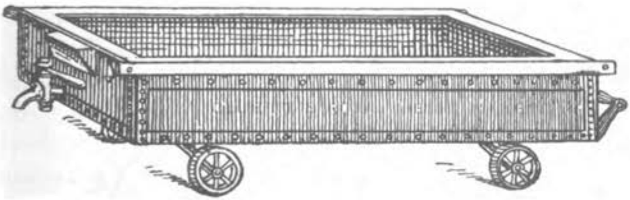


Fig. 107.

years at the leading dairy shows, and have invariably carried off the awards in competition with the old round ones.

Curd-Mills.—Fig. 108 is a drawing of H. Bamford and Son's Curd-Mill. All the fittings and bearings of these mills are galvanised, easy of access, and not liable to get out of order. The framing is of iron, and where desirable, malleable, instead of the ordinary cast iron is used, wrought iron being employed in parts.

The same mill can be had without the stand, and adapted for fixing on the top of a cheese pan or tub.

Cheese-Presses.—The varieties in cheese-presses are so numerous that we cannot even attempt to specify them all.

Fig. 109 represents one of H. Bamford and Son's Improved Iron Cheese-Presses. They are made single or double. The use of wrought iron where necessary gives strength; they are light, can be easily moved,

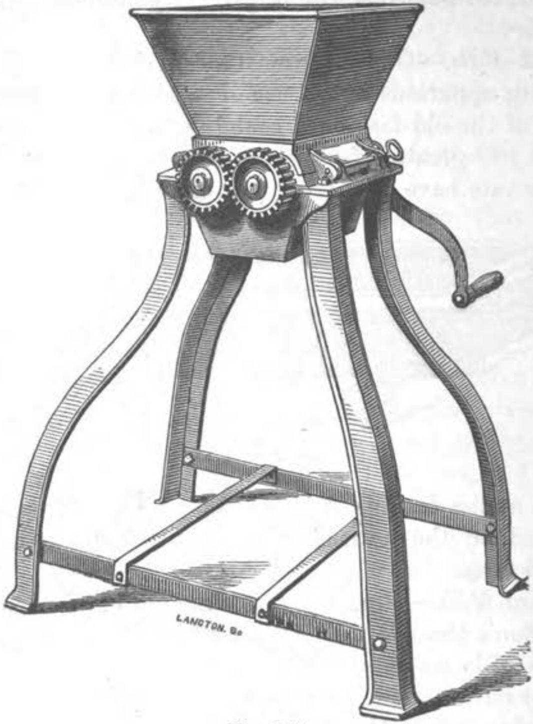


Fig. 108.

and stand within a small space. There is also the least possible labour attending their management; by merely turning the screw, the weights are raised and the pressure is then continuous, and does not diminish as the cheese sinks by compression. There are four weights supplied, the whole or a portion of which can be used as the state of the cheese requires.

An apparatus for making soft cheese is much used

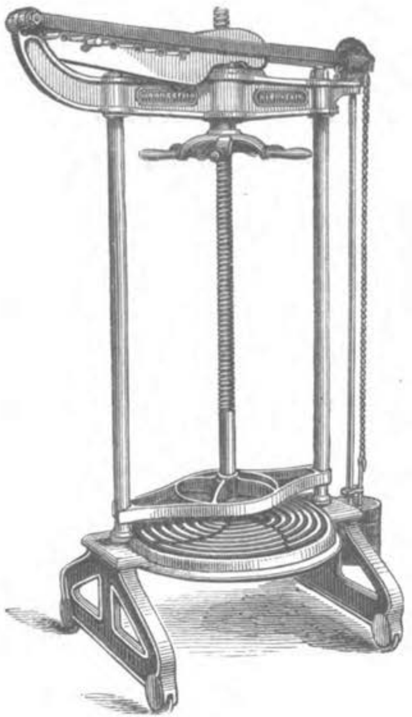


Fig. 109.

by continental dairymen. It consists simply of a large stage with long and short boards for dividing the masses of curd to form the cheeses. Special moulds and strainers are also used for cream cheese-making.

CHAPTER XVIII.

CLIPPING MACHINES.

Sheep-Shears.—The Sheep-shears in most common use have a single bow spring, with the bow and blades all one piece. In the engraving (Fig. 110) the shears have a double bow united by a rivet. The latter tire the hand less than any shears we have ever used. This is of great importance, as with the single-bow shears it is very difficult to get a pair in which the tension of the spring is such as to exactly suit the hand of the operator; whilst it is also necessary to employ shears having a spring of greater or less tension as the wool may be heavy and strong or thin and light. Again, the hand of the workman is stronger in the morning when he begins work than towards the close of the day, at which time less powerful shears are preferred. It has been designed to meet these difficulties by providing a movable fulcrum, which may be fixed at any point between the sides of a spring having parallel sides, so that by moving it from one end to the other, the tension can be regulated, and a single pair of shears thus made to answer all the requirements of the shearer. The fulcrum is preferably formed of a short coil of steel wire, of a diameter just sufficient to fill the space

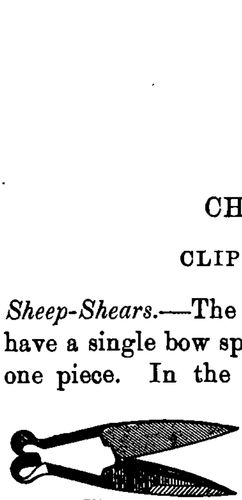


Fig. 110.

between the sides of the spring, which it clasps on one side through the ends of the wire being slightly hooked, whilst the elasticity of the coil makes it cling to the spring and retains it in its place, allowing it at the same time to be easily moved to any desired point. The friction of the fulcrum on the two parts of the spring further prevents, with the grip of the hand, any tendency which the blades have to slip by each other, commonly known as "buckling." This device is equally applicable to shears, the blades of which are united by a rivet, it being only necessary to introduce a spring on which to attach the fulcrum.

Horse-Clippers.—Fig. 111 is a representation of

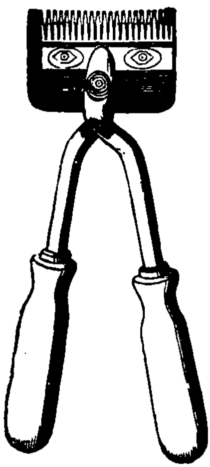


Fig. 111.

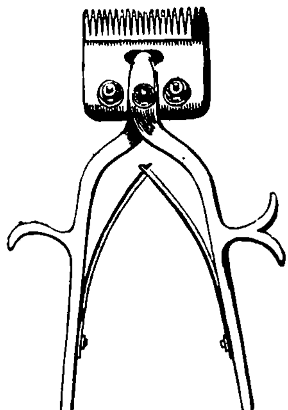


Fig. 112.

Clark's well-known instrument for clipping horses. It has now been many years before the public, and is acknowledged to be the best and cheapest in the market. In using this clipper, all that is necessary is to hold the instrument level and steady on the skin, pushing the lower blade forward as fast as possible, while working the upper blade or cutter by an oscillating motion.

Fig. 112 shows a one-handed clipper, for heads, manes, quarters, and difficult parts, leaving one hand at liberty to hold the horse, thus enabling the clipping to be performed by one man only. Each of these machines can be used for sheep-shearing.

In Clark's larger apparatus for clipping horses or sheep, a new principle in mechanics has been developed. This is a flexible shaft, through which the power is communicated from the driving-wheel to the shears, which are kept rapidly clipping as long as the driving-wheel turns, no matter in what position they are held, nor how much the driving shaft is contorted, even to bending it around the animal being clipped or shorn. This driving shaft is a spiral brass wire, one end of the coil being connected with a small wheel attached to the butt of the blades of the shears, and the other to a pulley driven by a band on the end of an arm, which is partly flexible, attached to the small frame that holds the driving-wheel. On the opposite side are another arm and shaft and shears for another shearer, each working independent of the other, and the machine, it will be seen, can be fitted with a third and fourth rod if required, so that from one to four animals can be operated upon at the same time. Or, in clipping a horse, by using two driving-rods, one man may clip the upper and another the lower and under parts at the same time.

The drawing represents a perspective view of the driving apparatus. Each turn of the wheel produces 32 cuts, and as a boy can easily produce from 80 to 90 revolutions per minute, the extraordinary speed is attained of 2,560 cuts per minute, with each driving-rod or set of shears.

Hedge-cutting and Trimming Machine.—An ingenious machine for cutting and trimming hedges has been introduced by Messrs. R. Hornsby and Sons, Limited. Its capabilities have been thoroughly tested on hedges of all kinds, with the result of proving that it is able, cheaply and expeditiously, to accomplish what has hitherto been a laborious and costly operation. The hedges which have been cut by these machines are growing well, and have become full growth from the

Fig. 113.

bottom to the top. Its general appearance is shown in Fig. 113; the following particulars will enable its mode of working to be clearly understood:—The machine is mounted on two road wheels of large diameter to secure light draught. Both wheels are employed in driving the working parts, the motion being communicated by an arrangement of gearing to one of a pair of knives, similar to the knives of mowers and reapers, but larger and of greater strength. These knives are carried by a sliding bar projected from the side of the machine. This bar with cutting apparatus is so arranged as to be capable of ready adjustment to suit different circumstances; the entire machine when set for work being under complete control of the man in charge, who rides upon a seat conveniently placed for making all necessary adjustments. The cutting apparatus can be raised to any required height to suit high or low hedges, or the level of the ground on which the machine may be travelling. It can also be set at any required angle, to cut more or less off the hedge, and to reduce its height or alter its shape as may be desired. Both sides of the hedge may be cut from the same side, so that the machine may be kept on that side which is most convenient. The side of the hedge nearest the machine is usually cut first, and then the bar lifted over the hedge and the angle of the inclination reversed, so as to cut the other side. The top may afterwards be trimmed if required (though this is not usually necessary), by setting the cutting-bar straight out from the machine, and the height the hedge is required to be left. The cutter-bar being constructed on the same principle as the paragon mower, swinging round the crank spindle, will work equally well on either side or at the top, and at any angle of inclination. The hedge when cut is Λ-shaped, of any required width at bottom, and of any height. The machine is worked by two horses, and requires only a youth to drive, and one man to manage and control the cutting, and the work accomplished is about five miles of hedge, cut on both sides and at the top, per day.

CHAPTER XIX.

POULTRY-YARD APPLIANCES.

Incubators. — Artificial incubators will be found a decided advantage, especially where very early chickens are wanted, or only laying fowls, that is, non-sitters, are kept.

Fig. 114 is a sectional view of Christy's Patent Thermostatic Incubator, of which our space will afford only a very general description.

A is a valve acting upon B, the mouth of air-shaft; C, rod connecting valve with the thermostatic band in the egg-drawer; D, the set screw for regulating the temperature; E, the screen protecting the valve A and the lever; F is the filling pipe; H, the top of the chimney, in the centre of which is the boiler; H* is the circulating boiler; I, lamp screen and stand; L, air-holes; M, the front of the drawer; N, the thermometer; O, the lamp; P, the wood slide to push lamp close up into the chimney; Q, the thermostatic band—when cold it follows the dotted line, when working it is pressed down at end attached to C by the power of expansion; R, R, circulating pipes; S, collar fitted at bottom of H; T, evaporating pan, covered by canvas; U, water-tank.

The rules for working are as follow: Fill the tank with hot water. Light the small lamp and set the regulating valve at the heat desired. After the eggs are placed in the drawer, if the lamp is trimmed morning and night, and the eggs turned once a day, no further attention is required.

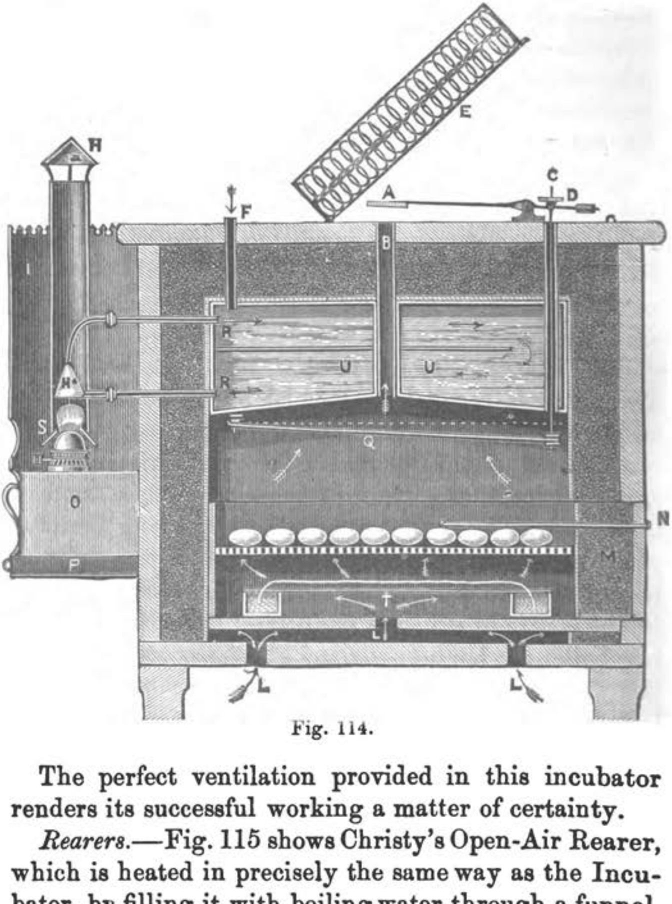


Fig. 114.

The perfect ventilation provided in this incubator renders its successful working a matter of certainty.

Rearers.—Fig. 115 shows Christy's Open-Air Rearer, which is heated in precisely the same way as the Incubator, by filling it with boiling water through a funnel, leaving it for twelve hours, and afterwards keeping up the temperature by a supply of boiling water once or twice a day, from one to two gallons each time, or more, if necessary. The operator must judge the quantity, according to the temperature of the atmosphere, making allowance for its variations, and also proportionately to the number of chicks in the artificial mother. The best temperature to keep up is about 60° to 70°, but by pressing the hand up towards the loose flannel, lining the bottom of the cistern, it can be at

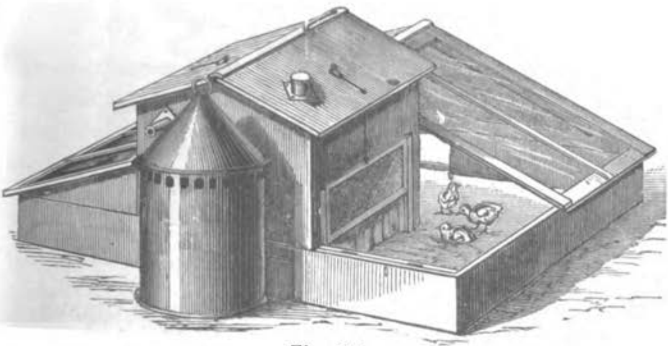


Fig. 115.

once determined if the heat on the backs of the young birds is sufficient or not.

The first night or two the sliding ventilated zinc doors can be closed, if judged advisable, and if the weather is very cold; but afterwards they should always be raised during the night, for if the chickens feel cramped for space, or too warm under the mother, they should be able to go outside into the fresh air.

Leaving open the zinc slides is also a guarantee against the danger of crushing and trampling, as, if the weaker ones are pushed by the stronger chicks, they simply come out into the tray, run round to the other side, and go in there.

Cramming Machine.—Several French Cramming Machines exist, but in all of them is the fatal defect that they are only available for liquid food. Fig. 116

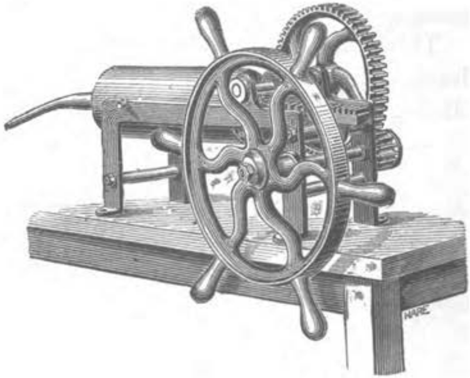


Fig. 116.

is a sketch by Christy of an English-made Crammer, which is sufficiently powerful to feed with almost dry food. It is worked with a wheel, which forces a plunger down the cylinder and out at the metal mouth into a rubber tube passed down the mouth of the bird to be crammed.

CHAPTER XX.

MISCELLANEOUS IMPLEMENTS AND MACHINES.

Steam Sawing Machinery. — Since the introduction of light portable engines, the demand for this class of machinery has largely increased.

The portable steam saw-bench illustrated in Fig. 117 has been specially designed by R. Garrett and Sons to suit the requirements of landed proprietors and others for country use. It is fitted with Lakeman's saw-guard, which insures safety for the attendant; and with adjustable fence for cutting parallel or bevelled work of every description to the greatest nicety. The respective advantages of a fixed and portable saw-bench are thus combined, and a most invaluable and inexpensive saw-bench for general purposes is produced.

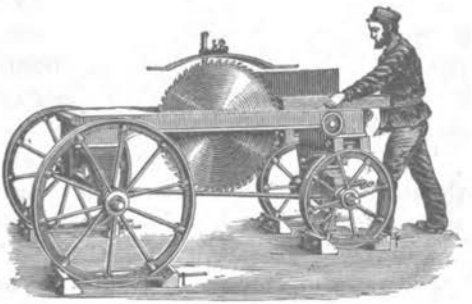


Fig. 117.

Fig. 118 shows a set of Marshall and Sons' steam sawing machinery in position cutting up timber at the place of its growth.

This plan of converting timber is found to be highly advantageous both in this country and abroad, as each part is self-contained and portable, and is very readily fixed down. The sawing machines are driven direct from the engine through belts from two separate fly-wheels, and the engine being constructed to burn wood, chips, and sawdust, fuel is supplied free of cost. The saws are flat circular pieces of steel, having teeth cut upon their outer edge. They are made of various sizes, and shaped for ripping up large stuff or for cutting small wood.

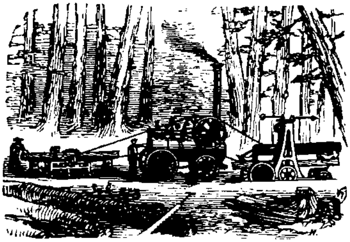


Fig. 118.

The saw has a hole in the centre exactly the size of the turned end of the spindle upon which it is placed, and another disc of iron is screwed upon it, pressing it and holding it securely against the other, and in its place, so as to run perfectly true. The movable portion of the bed-plate is then replaced, and rather less than half the saw appears above the surface of the table. A strap from the engine or from some part of the machinery in motion is placed upon the loose pulley on the spindle when the saw is required to be used; the strap is pressed towards the fixed pulley, which, from its shape, immediately runs upon and gives motion to the saw. It is necessary that the saw should revolve at a high speed, or it will not be effective.

Bone and Coprolite Mills.—The grinding of bones for manure is one of those operations that can only be well effected where the steading is equipped with a steam-engine. Steamed or boiled bones are, however, much easier to crush than raw bones, and steaming the bones in no wise impairs their efficacy when applied to the land. On the contrary, steaming or boiling renders the bones more readily assimilable as plant food; and, as a quick return is most wanted by the farmer, there is no doubt that super-heated bones, ground into dust, and drilled in with the seed, is the best possible method of using this valuable and highly fertilising manure.

Bone-crushing still continues to be done almost quite as a separate business, and the mills are large and expensive; but there is no reason why a small bone-mill should not be attached to every steading. In the few cases where this is so, they are found highly advantageous; for a greater or less quantity of bones can be collected on every farm or picked up in the neighbourhood; and when the farmer has to purchase the bones he can tell what he is paying for, which is not always the case when he buys prepared bone-dust.

Bone-grinding is effected by passing the bones through a series of toothed rollers arranged in pairs, the rollers being toothed or serrated in different degrees of fineness, and riddles are provided for sifting the bones into sizes, and they are then sold as quarter-inch bones and bone-dust.

One of Hall's small bone-mills, for farm use, is capable of breaking 3 tons of bones per day with a 3 horse-power engine, and separate the same into three sizes, viz: dust, $\frac{3}{8}$, and $\frac{3}{4}$ in. cubes.

The distinctive features of this mill are (1st) an improved method of driving the rolls by a combination of differential gear and friction, sheave and strap, with a better balance of the high-speed shaft than heretofore. This enables the rolls to be driven at a greatly reduced speed over the first motion shaft, thus increasing the power available for crushing the bones; yet it is capable of adjustment by hand, so that whilst crushing the hardest bone, it will slip in the event of a harder substance such as a horseshoe or piece of iron getting between the rolls. (2nd) The rolls are made to open and close for coarser or finer crushing, and when dealing with large bones they may be expanded by turning a couple of screws to rough the bones down for further treatment if necessary. (3rd) A revolving screen made of perforated steel plate is supplied with the machine when required with necessary driving gear. (4th) The frame of the mill being in one box casting, it is very rigid; stands firmly to its work, and improves the general appearance of the mill. It is self-contained, and requires no special foundation to be provided. These mills can be used for a variety of purposes in addition to crushing bones, as, for instance, in cracking nuts of all kinds where the shell is only to be destroyed and the kernel preserved. This is important where oil, &c., is extracted therefrom.

Price of mill complete, with screening apparatus, £60.

Fig. 119 is a section of Hall's "Victor" Bone-Mill, in which will be seen the latest improvements for the reduction of bones, necessitated by the demand for a finer quality of crushed bones

The upper rollers are composed of coarse serrated iron rings. One roll is adjustable to and from its fellow for coarsing or finer crushing, whilst a third or pulverizing roll is added underneath, composed of rings of fine serrated teeth, and running at a high speed, and in conjunction with the upper adjustable roll, so that any reasonable degree of fineness or pulverization may be obtained at one operation, and yet the machine may be used only for rough crushing by simply opening the top roll.

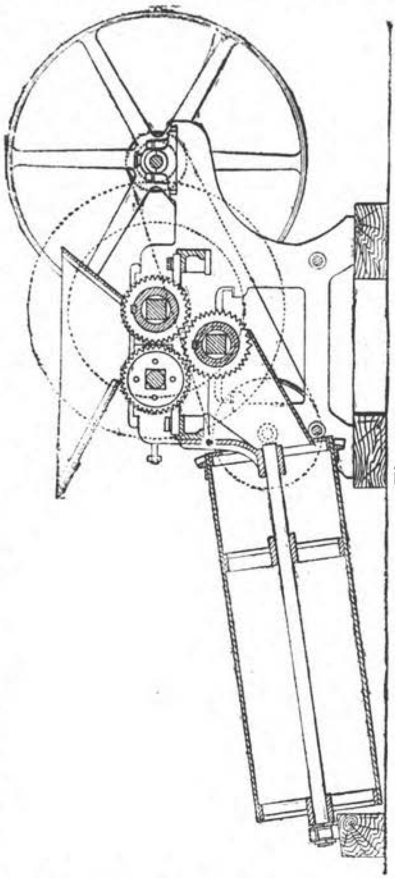


Fig. 119.

The essential feature of this mill, it is seen, is the addition of a third or pulverizing roller, with fine teeth, and running at a much higher speed than the two upper crushing - rollers, thus clearing the teeth and reducing still finer the crushed bones as they fall from the upper pair.

This mill is made in five different sizes, capable of crushing from 2 to 10 tons of bones per day. The price of the smaller size is £30.

These mills are equally suitable for grinding coprolite.

Apple-Mills.— The manufacture of cider in the apple-growing districts, Herefordshire, Devonshire, &c., is an operation of great importance, and conducted with all the care and attention that is bestowed upon any other process for converting the produce of the land into a marketable commodity. Cider is made from the juice of the apple.

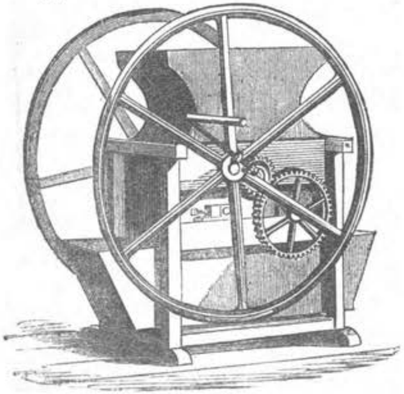


Fig. 120.

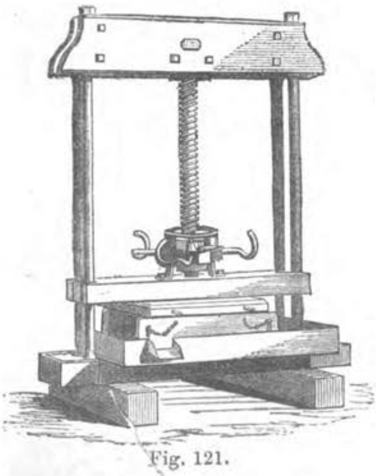


Fig. 121.

The old form of apple-mill has a wooden cylinder, upon the surface of which nails are fixed, the sharp heads of which project above the cylinder about one-eight of an inch. The apples are filled into a hopper placed over the cylinder, and led into a narrow cavity at the upper side of it. The cylinder is turned by hand, horse, or other power, and the apples are reduced to a fine pomace, grated, not pressed.

An improved Apple-mill, by the Bristol Waggon Works Company, is represented in Fig. 120. It is fitted with two pairs of rollers, the top rollers of wood, with thirty teeth in each, working opposite each other, thus taking a firm grip of the apple, which is crushed while passing through to the under rollers. These are of Pennant stone, accurately turned, so as to reduce the fruit to a pulp, and to crush the pip; this is very desirable, as it improves the quality and flavour of the cider. The feed can be easily regulated by means of a slide in the hopper according to the power. Two men will grind easily about ten sacks of apples per hour.

Cider-Presses.—An improved small screw Cider-press, by the same makers, is shown in Fig. 121. It is fitted with 2½ in. best wrought-iron screw and nut, and has a strong timber frame secured by wrought-iron plates.

Double-screw presses, on the same principle, are also to be obtained.

Harness-Brackets.—For heavy cart-horse harness the brackets require to be extra strong. Some excellent cast-metal fittings of this kind are supplied by the St. Pancras Iron Works. A breeching, bridle, collar, and double-rein bracket is allotted to each horse. The arrangement shown in Fig. 122 may be varied in the relative positions of the brackets. When the pad requires to be supported instead of hung, a different kind of bracket to the breeching one shown in the figure is used.

Implement-Racks.—No stable should be without these useful appendages for holding forks, shovels, brooms, &c. The racks illustrated in Fig. 123 answer the purpose admirably. By having a hanging-place for the stable implements they can be got when

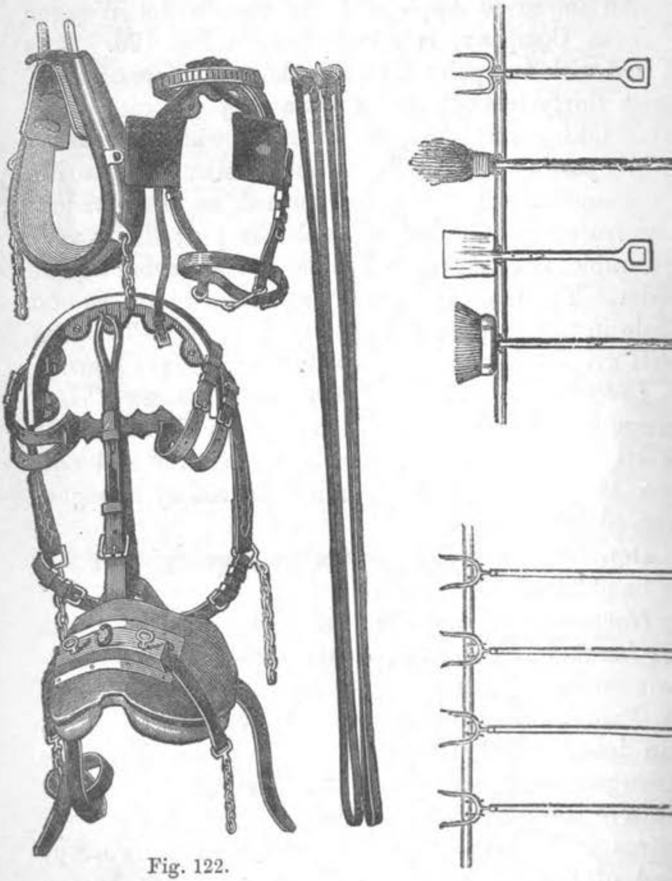


Fig. 122.

wanted; there is no fear then of their getting amongst the horses' feet; and the stable has a more tidy appearance.

INDEX.

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SCOTT'S FARM ENGINEERING TEXT-BOOKS

VI.

FIELD IMPLEMENTS AND MACHINES

A

PRACTICAL TREATISE

ON THE

VARIETIES NOW IN USE, WITH PRINCIPLES AND DETAILS OF CONSTRUCTION, THEIR POINTS OF EXCELLENCE, AND MANAGEMENT

PREFACE.

In no department of Agricultural Engineering has there been greater progress than in those wonderful modern implements and machines which have revolutionised the work of the field. The improvement in this direction becomes more marked every year, and nothing can show better that farming is being brought under the application of scientific principles.

Visitors to any great agricultural show, in any of the three kingdoms, will hardly fail to draw this very important conclusion from the sight of the vast array of agricultural machinery. It is found, too, that farm labourers, not quite so stupid as was thought, are capable of managing the new machines, and of adapting themselves to the improved style of work which these necessitate.

The Syrian farmer still cultivates the hillsides of Judæa with implements made after the pattern of those which were used in the time of King David, and there may be districts where the ordinary plough of an English agriculturist is really no very great advance on the wooden ploughshare of the ancient Briton. But circumstances, as the proverb says, alter cases. In his struggles with other countries the British farmer has called in the aid of the inventor. He has drained his land after new methods. The reaping-machine has abolished the sickle and the scythe; the threshing-machine has relegated the flail to the museum of curiosities; the steam-plough has in great part superseded the old method of breaking up the soil; the great army of haymakers has been driven from the fields by the tedding-machine and the horse-rake; and even the farmer's homestead and his whole surroundings have come within the influence of improvement.

One labour-saving device has quickly followed another, until a great proportion of all kinds of farm-work is now performed by the aid of machinery. Machinery, however, has not, if we except occasional temporary consequences of its introduction, deprived men of employment; it has merely changed the conditions under which they work. "There is, if not an ever-increasing need, an ever-increasing consciousness of need, of labour-saving inventions and machinery. And if these inventions should render labour twenty times as productive as it is to-day—should make this a general rule, that all human labour should produce twenty times as much as it does to-day—there would be no glut of products, as so many mistakenly apprehend. England herself, it is computed, now does the work, by means of steam and machinery, of eight hundred millions of men. And yet English wants are no more satisfied to-day than they were a thousand years ago."

CONTENTS.

LIST OF ILLUSTRATIONS.

FIELD IMPLEMENTS AND MACHINES.

CHAPTER I.

PLOUGHS.

THE plough is an implement for breaking up the soil, and was used, though in a primitive form, as far back as ancient history records.

The Old Testament speaks of ploughing with shares shod with stocks of iron or bronze.

The Greeks knew the wheel-plough.

The modern plough, with its mouldboard to turn over the broken-up soil, was invented in the Netherlands in the seventeenth century, but has since been much improved.

The first steam-plough was worked in England in 1832.

Various kinds of Ploughs.—Of late years the number of different purpose ploughs has multiplied amazingly. Amongst the chief varieties are the following:—

Wheel Ploughs.
Swing Ploughs.
Double Furrow Ploughs.
Multiple Ploughs.
Gang Ploughs.
Subsoil Ploughs.
One-way Ploughs.
Ridging Ploughs.
Paring Ploughs.
Potato Ploughs.
Steam Ploughs.
Draining Ploughs.

The Parts of the Plough.—A plough, whatever its special construction may be, consists of some or all of the following principal parts :—

1. The cutting parts—the *share* and the *coulter*.
2. The turning part—the *breast* or *mouldboard*.
3. The *frame* or *skife*, to which the share and breast are fixed, and which, with them, then forms the *body* of the plough.
4. The *beam* and *handles*.
5. The *bridle* or *head*.
6. The *wheel* or *wheels* for regulating the width and depth of the ploughing.

The Plough-Share.—The share is that part which cuts the slice or earth horizontally. It is fixed into a projecting portion of the lower part of the plough body, called the sole or slode, which is a movable piece secured to the under side of the frame.

Various forms of plough-shares are used for different kinds of ploughs and for different kinds of work. The accompanying illustration shows the variety of shares sent out with Ransome's ploughs, and the kind of work they are suitable for.

Formerly plough-shares were made of wrought iron, now they are invariably of cast metal.

The important invention of the chilled share was patented by Robert Ransome in the year 1803, and has come into extensive use, though even now its advantages are not fully known. These shares have the *under surface as hard as steel,* whilst *the upper part of the share is soft and tenacious.* By reason of this construction, *the upper part wears away, and the cutting edge of the share always remains sharp;* the draught of the plough is uniform, and much less than when fitted with wrought iron or other shares, which wear blunt, and must from time to time be relaid, causing loss of time by journeys to and from the smithy.

These chilled shares are very tough and hard without being brittle, and they are comparatively inexpensive.

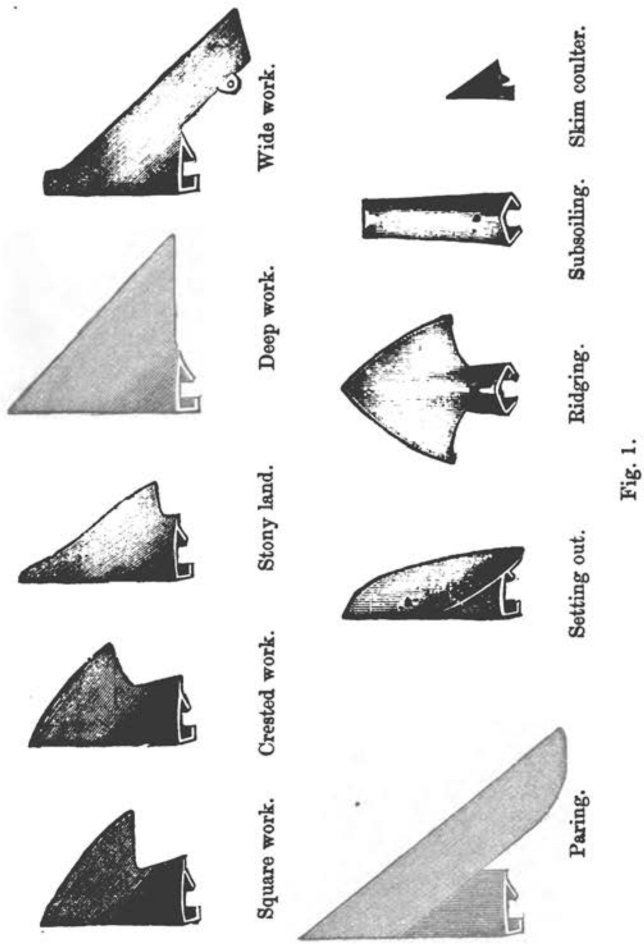


Fig. 1.

The Coulter.—This is a large knife, made very strong, of iron and steel. It is an important part of the implement, and requires considerable care and skill in its adjustment. Its use is to make the vertical cut, through which the plough moves. It is made sharp on the front side, and so strong as not to give or bend in any way while in use. The side of the coulter next the land is perfectly flat; the other side tapers towards the back. It is attached to the beam of the plough by its upper end, and fastened with a wrought-iron clip, which, by being made movable within a range of 5 inches along the beam, alters the angle which it makes with the sole-line of the plough. The upper end, or stem of the coulter, is made circular, and passes through two eye-bolts, one of which is placed above and the other below the beam; the ends of these pass through a plate, the ends of which are turned in, or kneed at right angles; these ends having circular notches, which embrace the coulter stem. This plate is upon the opposite side of the beam to that on which the eye-bolts and coulter are placed; and by tightening up the bolts the whole are bound firmly together. The circular stem of the coulter admits of the easy adjustment of its edge to the cutting of the furrow-slice. The coulter is not set perpendicular, but at an angle, generally of about 55° with the ground; but different kinds of land, and the same land under different conditions, require the coulter to be set at different angles.

The skim coulter is attached to the beam in front of the large coulter. The office of the skim coulter is to pare off and turn into the furrow, when ploughing lea or stubble, the herbage, &c., on the top of the furrow-slice, so that when this is turned over by the mould-board no vegetable matter is left untouched, again to take root, but is completely buried. The skim coulter is fastened to the beam by a wrought-iron clip, which embraces the stem. The clip is provided with screwed tails, which pass through a plate on the side of the beam opposite that at which the stem of the skim coulter is placed ; one of the tails is brought up by a nut securely against the beam. The "drag-chain," when used, is a member of the regular coulter; is attached to the bridle of the coulter, which is provided with a small weight or roller at its extremity. It is made to lie across the furrow-slice; so that while this is turned over, it drags in all stubble, &c., &c., which may lie on the edge, and buries it in the soil.

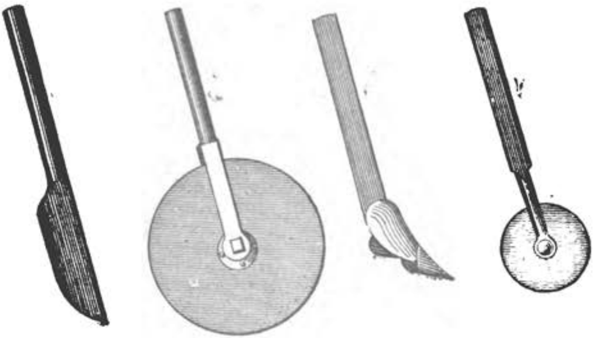


Fig. 2.

Edward Savage has recently patented an invention to furnish an attachment to a plough that will flay or cut the sod from off the furrow as it rises on the mould-board, thus doing away with the flay at present in use, and performing the operation with less friction, and consequently less work to the horses. It consists of a small horizontal cutting wheel fixed in suitable bearings to the frame of the plough. The bearings are firmly attached to the frame with set screws, and in such a position that the wheel shall come opposite to one just above the breast of the plough, and will be in a position to cut the turf from the furrow at the time the furrow begins to turn from the mould-board. An iron or other plate attached to a spring is fitted either to the same bearing, or otherwise suitably to the frame of the plough, and this, as the cutting wheel revolves, removes the turf, lays the grass and stubble, &c., under the furrow. The cutting wheel may be fixed in any other suitable manner so as to revolve nearly horizontally or parallel with the furrow, and the plate or spring for laying the grass and stubble may be used with or without the first part of the invention.

The Mould-board or Breast.—The mould-board is now invariably a plate of cast iron screwed to the plough frame, and is also called the turn-furrow or wrest. This term originally applied only to a portion of the mould-board, and was probably the wrest of the ancient plough which turned aside the earth.

The office of the modern mould-board is to receive the piece of earth upon its fore end after it has been cut by the coulter from the side and from the bottom of the share, and then turn it over continuously at a fresh angle.

Amongst numerous other improvements on the plough effected by them, the firms of Ransome, Ipswich, and Howard, Bedford, have furnished the modern English plough with mould-boards adapted to all classes of soils. The mould-board, indeed, which raising each slice of earth from its flat position gradually through an upright one, lays it over half-inclined on the preceding slice, is the essential acting part of the plough. It should perform this spiral transfer of a very rough material with an equal pressure both crossways and lengthways. The true shape is founded on mathematical laws, but is doubtless best determined by actual trial. The test of perfection in the work of a plough is, that the furrow-slice shall lie, after being turned over, in a perfectly straight line, not only unbroken but even uncracked. This unbroken furrow-slice

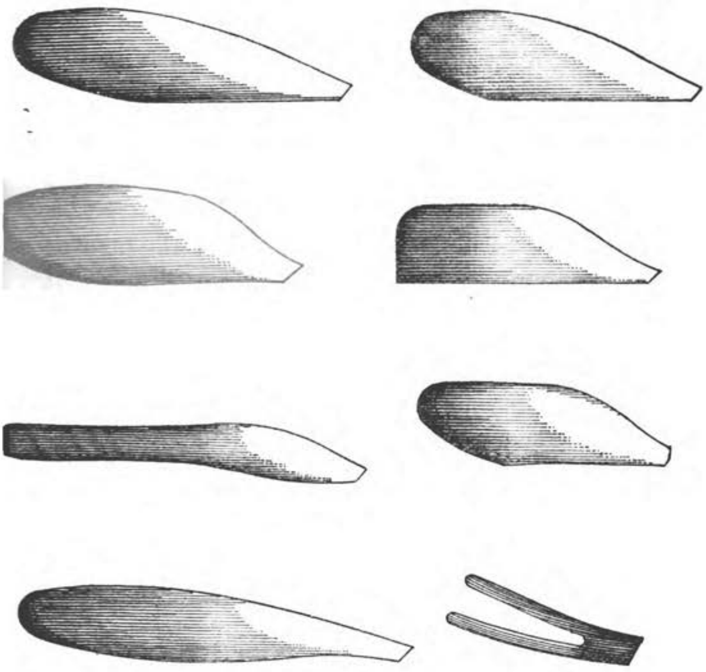


Fig. 3.

requires some length of mould-board; and it is urged on the other hand, on behalf of short mould-boards, that they pulverize the soil while they turn it over. Practical farmers, however, know that to pulverize is not the immediate object of ploughing land; but it may not be useless to state a further reason for the apparently excessive length of the mould-board of our improved ploughs. The chief resistance to the horses working the plough proceeds not from the weight of earth moved, which is insignificant, nor, unless the ground be unusually baked, from the act of severing the earth, but from two other causes, viz. *friction*, and, in certain soils, still more from *cohesion*. Now if the soil contain sharp sand there will be no cohesion; it will work freely off the mould-board, which will be kept bright, and the shorter the surface the less will the friction be. For sandy soils, therefore, short mould-boards may be the best. But many of our soils contain so much clay as will adhere to and fill up the hollow of a short mould-board, so that the furrow-slice will have to work not upon an iron surface but upon the most disadvantageous of all surfaces—one of rough loam—and the draught may thus be easily doubled by friction and cohesion together. Hence the length given to some of our mould-boards.

The object of ploughing is to turn the sod, or tilt over the furrow to a certain angle, so that the original surface is changed into the under surface, in order to kill the weeds or grass that may lie on the surface by burying them, and at the same time to expose as much of the soil as possible to the action of the atmosphere. The problem then which the mould-board has to solve is to effect this operation as uniformly and with as little waste of power as possible. This condition points out that the surface of the mould-board must be that of a screw, which might be produced by a line 9 or 10 inches long, which revolved uniformly about an axis through an angle of 135°, while at the same time it travelled along the axis through a space of 3 or 4 feet

The Frame is the centre portion of the implement to which the mould-board, beam, handles, &c., are affixed.

The Beam is a strong bar of iron, or beam of wood, to which the animals are yoked, one end of which is securely fixed to the plough frame, the coulter is also attached to it.

The Handles or Stilts are the long pieces of iron or wood held by the ploughman during the operation of ploughing, and which are so arranged as to give him the greatest possible control over the implement in directing its course, and preserving the depth and accuracy of the work.

The Bridle, Muzzle, or Plough-Head is a contrivance placed at the outer end of the beam, and to which the horses are yoked. It is constructed in a variety of ways, but the object sought to be obtained is the same, that is, to give a ready means of adjusting the line of drought so as to cause it to work steadily, and at the proper depth, by giving it, as it is called, more or less earth; this is effected by means of a movable portion of the plough-head called the *hake*, and which allows of the drought shackle being altered vertically, more upwards and downwards, or laterally to the right or left. The bridle is differently constructed by different makers.

In Wheel Ploughs the stem of the land-wheel, which precedes the skim coulter, has a vertical adjustment in the square eye of a loop screw or eye-bolt, which is secured to the beam by a nut. The furrow-wheel, which is nearly opposite to the land-wheel, has two adjustments—a vertical, to correspond with the vertical adjustment of the land-wheel, and a horizontal, corresponding with the breadth of the furrow-slice.

This horizontal adjustment is obtained by giving the axle a square continuation, which passes through and slides in a square eye-hole, attached to the bottom of the wheel-stem. The axles of the wheels are capped at both ends, which prevents the entrance of extraneous matter and the loss of oil. The friction is therefore lessened, and the longer wear of the axles secured. The draught-chain is attached at its inner end to the beam by a bolt, and its outer end passes through and is supported by an eye-bolt, at the bottom of a vertical bar, which is supported from the head or bridle. This bar passing through an eye-hole at the end of the bridle, is adjustable at any desired height.

The action of the plough may be described as threefold. First, the vertical cut by the coulter; then the horizontal cut by the share; and finally the turnings over of the portion thus cut by the mould-board.

Experience has, perhaps, done more in devising the best form of the plough than direct application of science. The actual problem of finding the best possible form of plough would be a very difficult one, even if all the conditions of the question were known; but owing to the varying conditions of the soil, it is almost impossible to devise any very vigorous statement of the problem which the best construction of a plough would involve. We may, however, examine what is known as to the principles on which the plough acts.

Various Styles of Furrows.—In the rectangular furrow, the width is too great in proportion to its depth, thus causing it to be turned too much over. The effect is to lay the furrow too much on its back, a position justly condemned by all practical men, as, though the grass may be well covered, the same amount of mould cannot generally be obtained for the covering of the seed as in the crested furrow.

Three of the most important advantages of the rectangular furrow are: (1) by means of it the greatest solid contents of soil can be turned over at the least expense of labour; (2) the greatest surface is exposed to the action of the atmosphere; and (3) from the furrow being wider, there is considerable saving of time in ploughing the same extent of land.

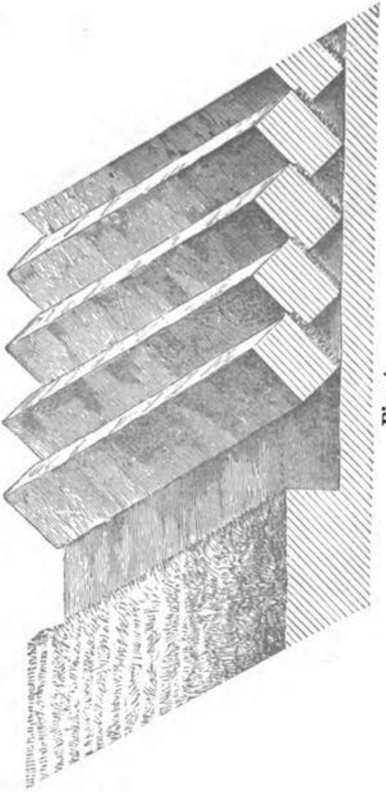
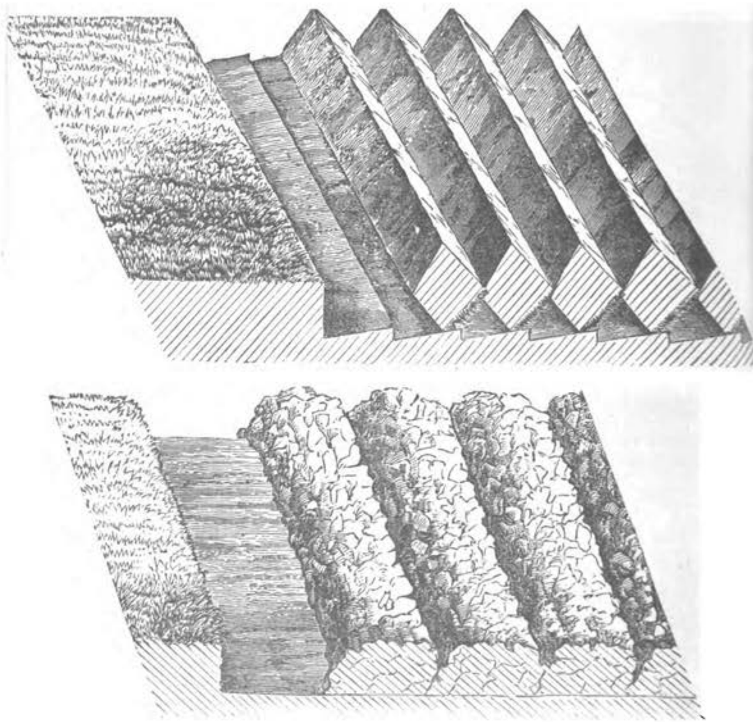


Fig. 4.

There are cases of lea-ploughing even where the rectangular furrow is as advantageous as the crested, such as in turf-ploughing in light friable soils with a tender sward of grass, and where the crop is to be drilled.

The crested furrow is obtained by cutting the furrow of an irregular form of unequal depths at the two sides, and in some instances slightly deficient in depth and thickness in its middle; such a furrow, when turned over and placed in its proper position, presents a sharp crest or shoulder.

A crest or shoulder in the lea-furrow is an advantage on most soils: (1) because the grass is more easily



Figs. 5 and 6.

buried by this form of furrow, and consequently the ground kept cleaner; (2) because there is more compactness and less tendency of the furrow to open up again after being laid over, as its edge falls into the hollow or groove in the middle of the furrow previously turned over; (3) because more mould is obtained, and less harrowing required for the covering of the seed; (4) because on account of the compactness of the furrows a more regular and equal braird, and earlier and more equal ripening of the crop, are produced. But while we give the preference to a crested furrow in lea-ploughing, we do not approve of this form of furrow in stubble-ploughing.

Points of Merit.—The following points in 1,000 were assigned the different parts of a plough at the R.A.S.E. trial at Hull.

	Perfection being
Weight	50
Price	50
Mechanical qualities and strength (engineer's opinion) / Simplicity (farmer judges' opinion)	200
Economy in power and draught	120
Time in trial with horses	
Perfection of work with horses	300
Flatness of sole of furrow	60
Cut on land-side	60
Neatness of laying slices and burying vegetation	100
Efficiency of skim coulter	60
Total	1,000

In the case of double furrow ploughs the judges did not consider the above satisfactory, and drew up a different list with regard to "points of merit," which, with the marks assigned, is given below.

	Perfection being
Price	50
Weight	50
Mechanical qualities and strength combined with simplicity	200
Economy of power of draught	250
Ease of management in work and in turning	100
Facilities of transport	50
Time in trial	20
Flatness of sole of furrow	80
Cut on land-side	20
Carried forward	820

	Perfection being
Brought forward . .	820
Packing and angle of furrow slice	100
Efficiency of skim coulter and perfect burying of surface matters	80
Making perfection of work	280
Total .	1,280

Mode of Yoking Horses in a Plough.—The horses should be harnessed as near to the plough as they can be placed without impeding the freedom of their step; for the closer they are to the point of draught the less exertion will be required to overcome the resistance.

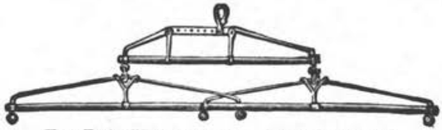
When ploughing with a pair abreast, the most forward and powerful horse should be worked in the furrow; but if the team be harnessed in line, and there be any difference in the height of the cattle, the tallest should be put foremost if he be in every other respect equal to the others.

When at work, they should be kept going at as regular and good a pace as the nature of the work will permit; for they are thus more manageable, and the draught easier than when slow. By due attention to this the heavy soil will also cling less to the coulter, and the land will be found to work more freely.

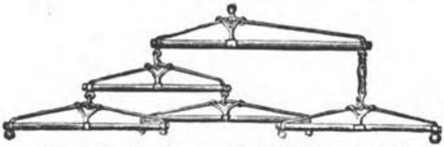
When ploughs are intended to be worked with 3 horses at length, or working in a line, the beams must be set accordingly to ensure correct draught, and therefore it should be specially mentioned when ordering a plough.

Howard's Improved Iron Tubular Whippletrees.—These whippletrees have recently been improved by connecting the "truss" rods to solid forged oval eyes on the ends of tubular bars. This alteration, without adding to the weight or price, considerably increases the strength of the whippletrees.

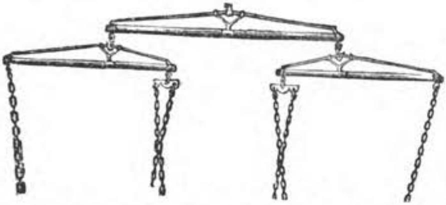
In proceeding to "set" the cutting parts so that the implement may work easily, the first thing to be noted



For Pair Horse Team. Price, 18s. 6d.



For 3 Horses abreast, suitable for Double Ploughs. Price, £1 10s.



For 3 Horses abreast, suitable for Harrows, &c. Price, £1 4s.

For 4 or 6 Horse Teams, suitable for ploughing or other purposes.
Price, 4-Horse, £2 15s.; 6-Horse, £4.

Fig. 7.

is that the plough stands upright. The next is that the edge of the coulter be set directly forward; at least, that the land side of it run in a parallel line with the land side of the head; and that there be no turning of it to the right or left, to cause the plough to take a broader or a narrower slice, a method too frequently resorted to, without considering the bad effects in point of resistance; nor is this bias at all governable—it increases with the solidity and diminishes with the looseness of the soil. The point of the coulter should never be so far forward as the point of the share, and always a good way behind it in a stony land. The former should also point a little way to the left of the land side of the latter.

A plough is made *to go deeper* in the following ways:—

1. By lowering the back-bands or increasing the distance of the horses.
2. By putting the muzzle higher in the index of the beam.
3. By slanting or giving the coulter a greater point forwards.
4. By lengthening the share.
5. And in the case of wheel-ploughs, by raising the land-wheel.

There are many ways of *making the plough take a broader slice*, or "giving her more land," as it is commonly called, but the only objectionable plan is of making the horses go a little wider. It may be done by giving the furrow-horse the longest end of the main-tree, but consequently the land-horse will bear more than an equal share of the draught. It may be done by hooking in or drawing from the right side of the muzzle, which to an inch or two from the centre may be allowable, and in general may be the most practicable; but wherever carried to three or four inches or more is highly reprehensible, as the plough is made to go in a distorted way, and forced out of its natural line. It may be done, too, by setting the coulter more to the left; and this, if the edge stands as before directed, may be admissible to a small extent, but if carried far out, its land-side and the after-part of the plates are made to bear all the strain or friction which should fall equally on the whole.

The contrary measures to those adopted for making the plough go deeper and take a wider furrow may be resorted to in order to make it take *a furrow of less depth* or *of less width.*

Plough Sledge.—Fig. 8 is an engraving of Howard's Plough Sledge, which will be found very useful for removing ploughs from one part of the farm to

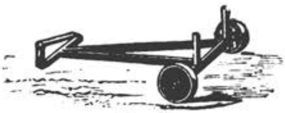


Fig. 8.

another. The wear of plough slades or soles by sliding on the roads is avoided, as well as the liability to strain. The breakages which often take place in loading and unloading are also obviated.

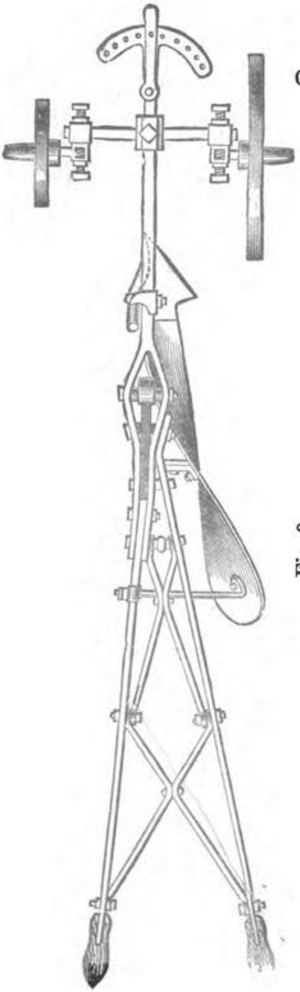


Fig. 9.

CHAPTER II.

GENERAL PURPOSE PLOUGHS.

Ransome's Wheel Plough. —Fig. 9 gives the plan of one of Ransome's Newcastle ploughs. These ploughs are strong, simple, and light in weight and draught. The beam embraces the frame, and is consequently extremely rigid. The handles are braced diagonally, giving great strength and power over the plough. They can be fitted with different breasts to suit any soil or kind of work. The shares and wearing parts are of the best quality. The adjustments of the wheels are quite simple, so that no unnecessary time is wasted in setting them. The wheels have a long axle, completely boxed in to exclude dirt.

An enlarged view of the fore end of this plough, showing the wheels and attachment to the beam, is given in Fig. 10. It will be seen that the wheels are attached by means of movable sockets to each end of one cross-bar running under the beam, which gives great steadiness to the plough. The set screws are so placed that they can be easily and quickly altered when it is required to vary either the width or the depth.

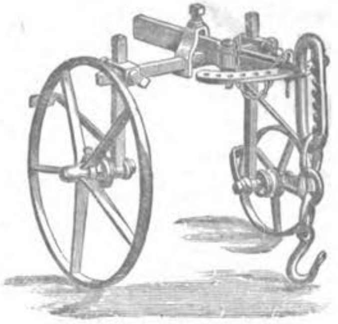


Fig. 10.

Howard's Champion Plough.—This plough has been in great demand for many years. It is suitable both for light and heavy land, for whilst light enough for a pair, it is strong enough for three or four horses, and is

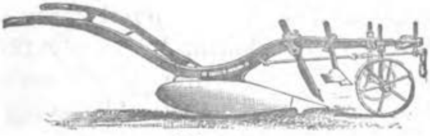


Fig. 11.

recommended as a most useful two-horse plough for working from 4 to 8 inches deep.

In addition to ordinary ploughs, by a change of bodies the various processes of paring, digging, ridging, subsoiling, and potato raising may be performed with these ploughs, three bolts only having to be moved.

Howard's Simplex Plough.—The Simplex plough is light in appearance, but from the sound mechanical principles adopted in its construction it is one of the strongest ploughs ever produced.

The customary main frame or weighty cast-iron body is entirely dispensed with, and as a substitute the hinder part of the beam, instead of running through in the ordinary way to join the handles, is curved downward towards the share. This curved end of the beam is embraced by a pair of wrought ribbed cheeks, the space between the cheeks forming a recess for the reception of the curved end of the beam, as well as the neck for carrying the share. In order to ensure great stiffness without adding to the weight the beam is T-

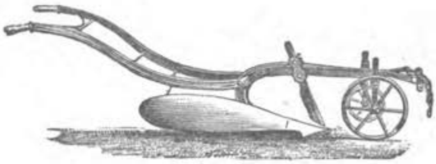


Fig. 12.

shaped, being formed with a wide flange on its upper edge.

This plough is fitted with a novel form of head, which enables the ploughman, by simply turning a handle, to regulate the line of draught without stopping the horses, thus effecting a considerable saving in time in the course of a day's work.

Swing Ploughs.—Of the comparative merits of wheel and swing ploughs much has been said and written by many persons interested in the subject, and the balance of evidence thus given in favour of each is decidedly on the side of the wheel plough.

The fact that swing ploughs consume more power for a given amount of work than wheel ploughs is probably owing to their being less steady in work, and is a strong argument against them.

When the land is wet and sticky, causing the wheels to clog and drag, the swing ploughs may have the advantage; but under such conditions the land ought not to be ploughed.

It does not appear that any direct law in mechanics is able to account for the fact that a wheel on the end of the beam of a common plough, or on the end of a turnip drill scuffler, enables the implement to take and keep a better hold of the ground than when the implement is drawn from the end of the beam, as a swing plough is pulled. It may be accounted for by no positive law, and yet be a fact, as it is most certainly a truth. The shoulder of the horse being higher than the beam of the plough, an uplifting power of some degree is exerted by the force of draught, which in the wheel plough is expended on the wheel, and is there stopped, proceeds no farther, and leaves the share in the ground undisturbed. In the swing plough the uplifting power meets with no opposition, proceeds along the beam, reaches the share, and lifts it from the ground. This simple observation may account for the fact above stated, and supply the place of mechanical law.

Fig. 13.

Fig. 13 shows one of Ransome's Newcastle ploughs fitted for swing ploughing. In order to give the ploughman greater command of the implement it is fitted with long handles, and it also has a shorter beam than in wheel ploughs.

In rocky or newly cultivated land the swing plough is especially valuable.

CHAPTER III.

TURNWREST PLOUGHS.

TURNWREST ploughs are made on four different plans. First, the mould-board turns over from left to right, and *vice versâ*, as in the American hill-side plough. Second, one or more plough bodies revolve on a horizontal axis forming the beam, one set standing vertically while the other is at work. Third, two or more right and left hand ploughs are balanced, as in the steam plough, and used in the same manner. The fourth and last plan, which was patented by Mr. Muriston in 1876, is the only one that calls for special notice. Mr. Muriston places two ordinary plough bodies, a right-hand and a left-hand one, back to back, with the ends of their turn-furrows almost in contact. This he attaches firmly to a small wrought-iron frame, supported on the central wheel, which acts the part of slade, and upon which the two bodies balance. The beam and handles are like those of an ordinary plough, and are pivoted to a vertical stud rising from the centre of the plough-frame already described. They can thus be swung round horizontally, whilst the plough bodies themselves remain stationary and looking in opposite directions. Catches, under the control of the ploughman, are provided to fix the beam and handles in the proper position for ploughing in either direction, and when the implement has arrived at the end of a furrow the horses in the act of turning bring these into the line for the return journey.

Ransome's (Skelton's Patent) Turnwrest Plough.—These ploughs are intended for hill-side ploughing, and for preparing the land for mowing and reaping machinery, as they turn the furrows all one way, and consequently leave no open furrows. They are very light in draught and easy to hold. They are turned at the headlands like an ordinary plough, and by the movement of a lever the share is turned over, and one breast is put into its proper position for work, while

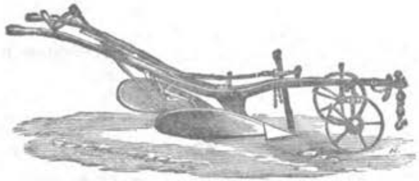


Fig. 14.

the other is raised and carried clear on the land-side. The coulter is moved by a separate lever to ensure its being set rigid.

To cultivators by steam-power these ploughs are especially useful, as there are always some portions of the field left unfinished, either as headlands, corners, irregular pieces, &c., which cannot be economically worked by the steam tackle.

Howard's New Patent Kentish Turnwrest Plough.—This implement was brought out to meet the requirements of farmers in the hilly districts of Kent and Surrey, where the furrows are all turned in one direction, generally up-hill. This plough was thoroughly worked upon different farms in Kent and Surrey before being brought before the public, and valuable suggestions during these experiments were made by some of the leading agriculturists of these counties.

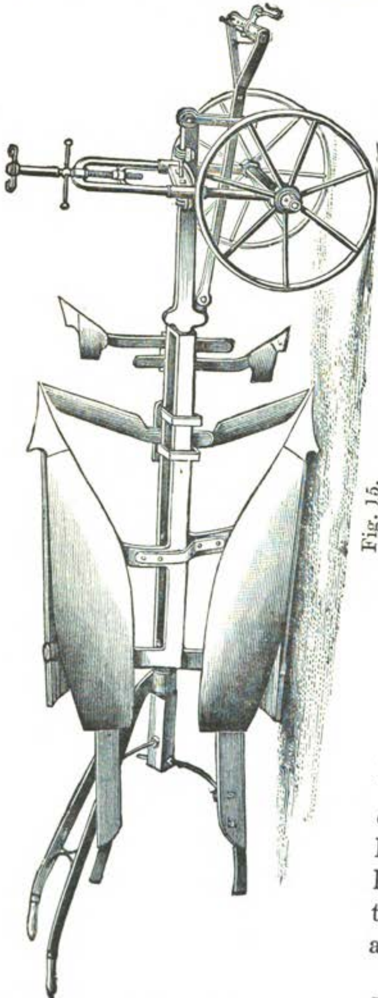


Fig. 15.

The mould-boards or breasts of the plough are modelled on Howard's Kentish plough pattern, and are fitted with pressers and knives for completely turning over the furrows and leaving them in the approved "hare back" form.

The plough can be readily adjusted to any desired width or depth of work, can be turned over from right to left with the greatest facility, and by a single lever is instantly locked rigidly with the fore-carriage or as quickly released.

Howard's Balance Plough.—The plough shown in Fig. 16 is made on the well-known balance principle so long adopted for steam ploughs.

The screw adjustment to the wheels allows the depth

Fig. 16.

to be regulated without trouble or loss of time, and with the disc guide wheel there is the further advantage of a wider wheel carriage, which ensures steadiness in working on hillsides. These balance ploughs are much used in Devon and Cornwall, and on sewage farms in other counties where, for the purpose of irrigation, it is necessary to lay the land level without ridges or open furrows.

Murray's One-Way Plough.—This plough is constructed by having two bodies attached to a lower beam standing in reverse positions, as will be seen by looking at the illustration.

The main beam and handles are attached and can be swung round on a stud in the centre, so that on the

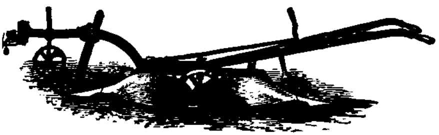


Fig. 17.

plough arriving at the end of the furrows the attendant moves a small lever which draws out the lock, and the horses then turning round move round the beam on the stud until it comes to position with the other body, when it is again locked by reversing the lever; the horses then move on for another furrow without the position of the bodies ever changing. A wheel in the centre acts as a sole, which completely balances the plough for both bodies, and considerably reduces the friction.

The advantages gained by this plough are as follows: Ploughing can be commenced at one side of a field and continued until the whole field is ploughed, consequently saving considerably in time both in "feering" and finishing the ridge. These two operations often taking more time than ploughing the whole ridge, less time is lost at the end, as the turning may be termed self-acting, and the time is saved going across the headlands.

One of the principal advantages is the furrows all being laid one way and no open furrows being left, leaving the field quite level and in a well-prepared state for the reaping machine in harvest—one of the greatest obstacles to the using of the reaper being open furrows and high-crowned ridges. By the use of this plough these are entirely done away with, and the reaper passes over a level surface, working much more pleasantly and lasting much longer by not being exposed to the severe shocks in deep furrows. A shorter stubble also will be got than can be by the present system.

Another great advantage will be in using this plough for hilly ground or steep land, obviating the necessity of going up-hill, which is so severe on the horses.

The general arrangement has been studied to give lightness of draught. This has been reduced to the lowest possible degree by the insertion of a balance anti-friction wheel, which carries the weight of the plough, doing away with all unnecessary weight that is not required for strength.

It is quite easy work for two horses, the whole arrangement is so simple and complete. The ease with which it can be managed makes it a great favourite wherever it is introduced, while the style and quantity of the work done is just what is required in modern farming.

CHAPTER IV.

SPECIAL PURPOSE PLOUGHS.

Howard's Bullock Plough.—This is a light but strong plough, intended for one horse or a pair of mules, to work from 3 to 6 inches deep. It is well known throughout Europe and the colonies, and is worked with facility by oxen with a draught pole as illustrated, or by horses with whippletrees and chains.

Pulverizing Plough.—Fig. 19 represents one of Ransome's Newcastle ploughs fitted with a digging breast, so called from the work which it performs resembling digging. The breast is short, and has two prongs or arms with a quick turn. It is intended for use in the autumn, and no better tool can be found for breaking up stubble, as it leaves the land loose and open, and in the best state for the sun to act upon it and kill the weeds. The land can afterwards be easily cleaned with a cultivator or harrow.

Howard's New Deep Plough.—This plough is particularly suitable where a deep pulverized furrow slice is required. For summer fallowing, for destroying weeds and twitch, as well as for autumn ploughing, to lay the land rough and open for the fertilizing influence of the winter frosts, this plough will be found admirably adapted. The wheels are attached to the beam by a single cross-bar, and can be readily adjusted to various

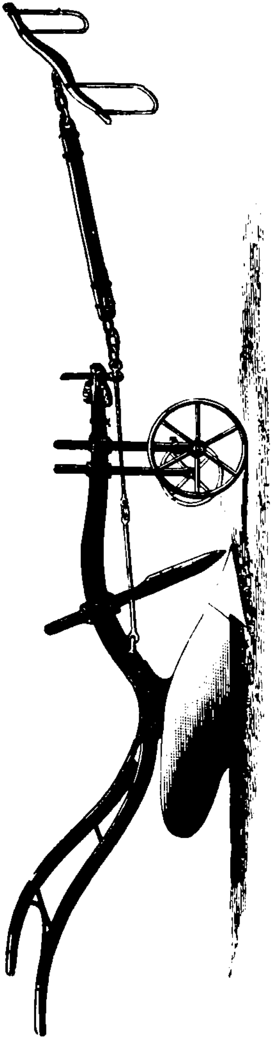


Fig. 18.

Fig. 19.

widths and depths. This plough is very suitable for vegetable growers, being light and strong, and calculated to turn a deep furrow with little power.

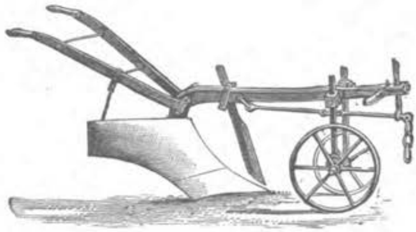


Fig. 20.

Ransome's New "Garden" Plough.—This plough is intended for ploughing in market gardens and districts where a deep, broken furrow slice is preferred. It is also adapted for burying weeds, &c., and for laying up the land in autumn. The adjustments are very simple.

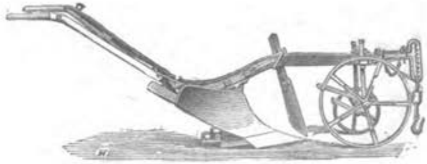


Fig. 21.

The plough is light and stong, and can be fitted with 2 wheels, or 1 wheel, or as a swing plough, as desired.

Paring Plough.—This plough, by Vipan and Headley, is adapted for paring any required thickness, varying from 1 to 3 inches.

It is used for paring old pasture land when about to be brought under cultivation.

It is also admirably adapted to pare stubbles in the autumn. The depth can be regulated, and a pair of horses will with ease pare from 1½ to 2 acres per day.

When using this plough let down the side cutter to the depth required.

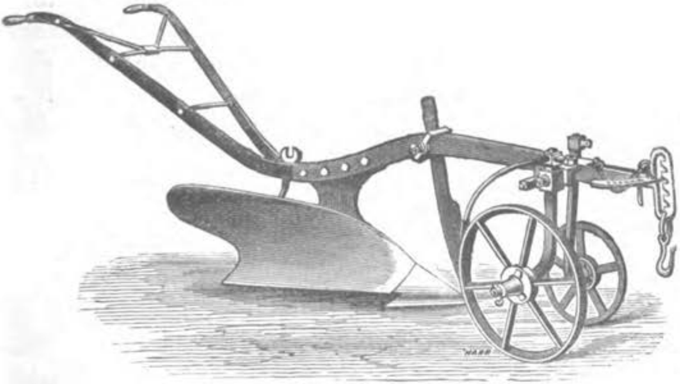


Fig. 22.

Parer and Seed Coverer.—This implement of Ransome's is intended for covering with soil seed which has been sown broadcast. The small shares and breasts are set 6 inches apart, covering a width of 2 feet in all,

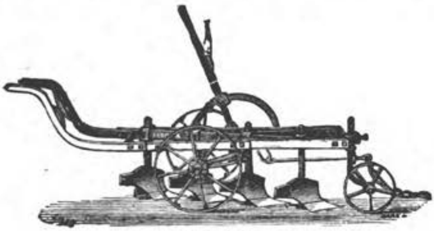


Fig. 23.

and are suitable for working from 2 to 4 inches deep; the seed then comes up in tolerably regular rows.

This implement is also very useful for paring the surface of stubble fields. It is fitted with patent double lifting wheels and long lever for adjusting the depth and lifting the plough out of the ground for turning. The average draught is from 2 to 3 horses.

Ridging Ploughs.—These ploughs are intended for ridging or moulding up beet-root, potatoes, or other plants sown on the ridge, and for opening water furrows. These operations are sometimes performed by a single-breasted plough, which has to go up and down the field

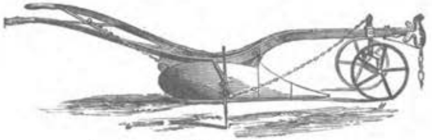


Fig. 24.

to accomplish the same work which the ridging plough effects in one journey. When used for setting out land, a marker is attached to the plough, which saves the trouble of measuring or dividing the land before commencing work, as the plough whilst making one furrow is making a course for the next.

They are also largely used for breaking up stubbles, leaving the land in ridges about 27 inches wide, a plan adopted by many practical farmers in preference to ordinary ploughing, inasmuch as about three times the extent of land can be turned over in a day with the same power. The ridges, after being well weathered, are split or opened out.

By removing the breasts and marker it may be used for subsoiling; and again, by attaching a hoe frame and cutter, a hoe plough is formed, suitable for cleaning land between rows of plants sown either on the ridge or flats.

Pulverizing, Subsoil, Ridging, and Potato Bodies.—All Ransome's ploughs may be fitted with the different bodies shown in Fig. 25. The ordinary body is very easily removed, and when the other one is substituted the plough is as strong, and equally adapted for the purpose to which it is then applicable, as if it had been originally constructed for that use only.

Howard's Single Subsoil Plough.—This is a strong implement, the same in every respect as Howard's Champion Plough, but fitted with a subsoil frame instead of an ordinary plough body. The draught is light, and the plough is easily turned at the land's end.

Howard's Double Subsoil Plough.—This is the strongest and most effective horse implement yet produced for the purpose of breaking up the close hard soil below the furrow, often rendered impervious to air and water by the trampling of horses. It moves the whole of the ground, and this with as little draught as most single-tined implements. This plough is a most useful and efficient implement for breaking up headlands after the steam ploughing engine.

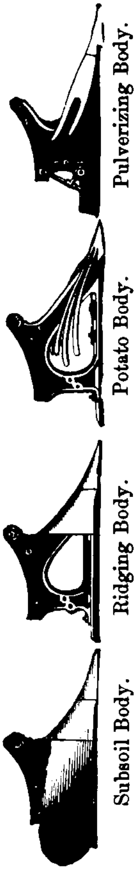


Fig. 25.

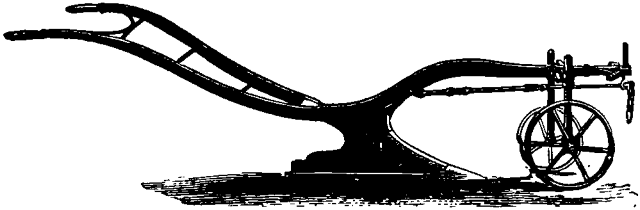


Fig. 26.

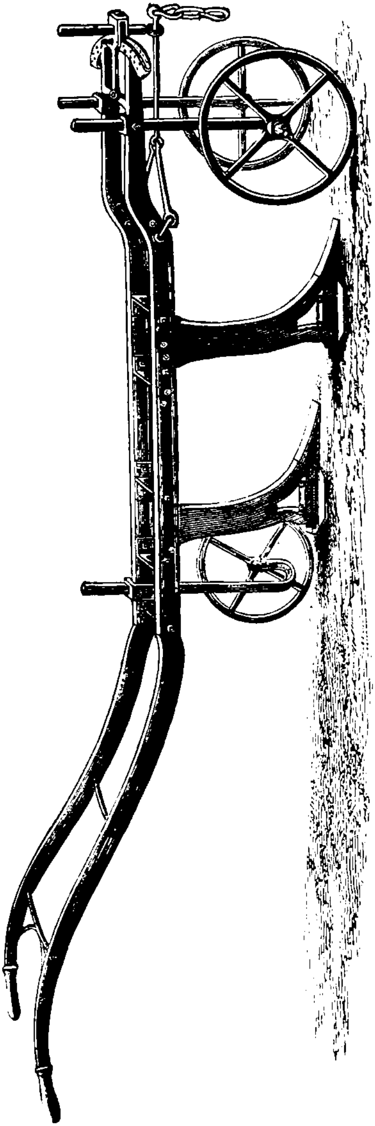


Fig. 27.

Ransome's Single Plough and Subsoiler Combined.—This implement was awarded the first prize at the Great Knutsford trials, February, 1877, accompanied by the following remarks from the judges: "We commend the plough to the public as a first-class implement. It is quite on a new construction, and stirs the soil at least 4 inches under a beautiful seed furrow of 6 inches."

The subsoiler works at the bottom of the furrow, and as soon as the bottom is pulverized the hind plough turns a furrow completely over the subsoiled portion, which is never trodden by the horses, as they always walk on the solid bottom.

The patent claw, shown on the under side of the subsoiler, comes into contact with the ground when the

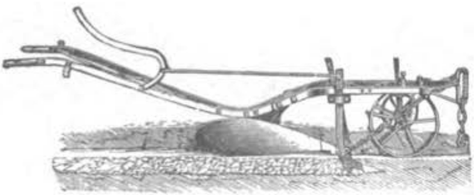


Fig. 28.

lever is released, and brings the subsoiler into work, when the principal strain is taken by a strong chain which leads from the head of the plough to the bottom of the subsoiler.

This is a most efficient way of subsoiling, and will work well to a depth of 12 inches.

Ransome's Double Plough with Subsoiler.—This implement is intended for use either as a double plough, turning over two furrows at a time, or to plough a single furrow and subsoil another.

It will be seen by the engraving that the subsoiler turns upon a centre under the beam, and is drawn out of its work by means of the lever at the right-hand side of the plough.

As soon as the subsoiler comes into work, the principal strain is taken by the strong chain which leads from the head of the plough to the bottom of the subsoiler, so that by means of this patent arrangement, the plough is much less likely to be strained than when the whole work of the subsoiler comes directly on to the beam.

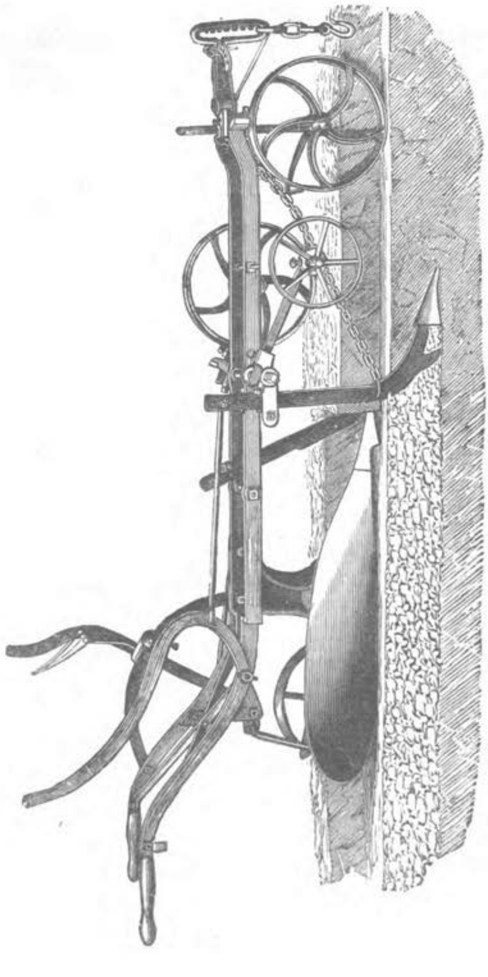


Fig. 29.

CHAPTER V.

DOUBLE FURROW PLOUGHS.

THESE implements are now attracting so much attention that it will be well to consider what are their special advantages, and what actual saving can be effected by their use. The result of such investigation cannot fail to show that it is a matter of considerable importance to almost every farmer in the United Kingdom.

Although double ploughs have been made for very many years, yet it is only within the past few years that special attention has been paid to them, and their real value at all generally acknowledged by agriculturists. The objection to the early plough of this class was the want of the proper means for raising and turning in at the headlands; but this difficulty has been surmounted in the modern improved double furrow plough.

Their advantages are :—

1. They will do twice as much work as a single plough.

2. They rarely take more than three horses to do the work of four on single ploughs, whilst on light land two horses will often be found sufficient to work them.

3. One man only is required to work a double plough, as when three horses are employed they are driven

abreast, so that the ploughing is accomplished with half the manual labour.

4. The bottom or pan of the furrow is not so much trodden as in single ploughing, as the furrow horse only walks in every second furrow instead of every one.

5. In hill-side ploughing two horses are generally sufficient to plough two furrows down hill, and on coming up hill by allowing the front plough to slip in the previous furrow they can take one furrow up hill, thus doing three furrows in each round, instead of two with the single plough.

6. On many soils, especially those of a heavy, wet, sticky, or spongy character, a great saving in draught is effected by the use of friction wheels instead of a slade, so that the plough runs entirely on wheels, which often enables three horses to do the work of four with equal ease.

7. A subsoiler can be fixed to a double plough instead of the front plough. By this arrangement the furrow is subsoiled directly after the tread of the horse, and the plough behind turns the furrow-slice over the subsoiled portion.

8. All kinds of work, clover land, stubble, crossing, digging, &c., can be done with a double plough on all soils. The ridges can be easily and quickly set, and the finishes or open furrows made as well and as quickly as with a single plough, so there are no obstacles to their general use.

9. The following calculation shows the annual saving effected by using double ploughs on a farm of 300 acres of arable land. Six men and twelve horses would be required on such a farm to work six single ploughs, whereas three men and nine horses would

work three double ploughs, thus saving three men and three horses. The horses might be entirely dispensed with by careful management, and the men during the time they would have been engaged in using the single ploughs. These 300 acres of wheat, clover, peas, beans, barley, oats, sunnerland or root crops, would take at least two ploughings each per acre on an average, or say 600 acres of ploughing. Taking 1 acre per day as the work of each single plough, or 2 acres per day as that of each double plough, the ploughing would occupy seventeen weeks.

The following calculation will show the saving effected :—

	£	s.	d.
Interest on the value of 3 horses at £30 = £90, at 5 per cent.	4	10	0
Annual decrease in value at £2 each	6	0	0
Hazard of loss at 5 per cent.	4	10	0
Annual value of food, 3 horses at 12s. per week	93	12	0
Shoeing and farriery at £1 each	3	0	0
Wages of 3 men for 17 weeks at 10s.	25	10	0
	137	2	0
Deduct interest on value of 3 double ploughs at £10 each, at 5 per cent.	1	10	0
	£135	12	0

Say a net annual saving of £135, which is equal to 9s. per acre on the whole farm. £35 would be more than sufficient to purchase three new double ploughs, and leave a clear saving in the first year of £100.

Fig. 30 is an engraving of Ransome's Patent Light Double Plough, R.L.C.D., for light land, fitted with a patent hemispherical (or bowl) land wheel, which makes the plough very easily turned at the headlands. It is fitted with adjustable beams, and will plough two furrows, each from 7½ to 10 inches wide, and from 3 to 8 inches deep.

On reaching the headland the ploughman has simply to turn the plough over on its left side on to the skid

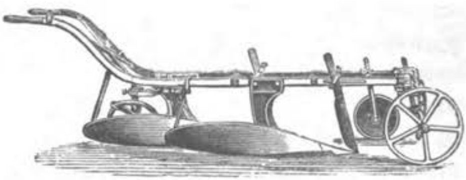


Fig. 30.

and hemispherical land wheel; it can then be turned easily in either direction.

Ransome's double-furrow plough, with patent double lifting wheels, is illustrated in Fig. 31. This implement is made in two sizes, adapted for general purposes, and for light and mixed soils.

The arrangement for lifting the plough out of work and turning it at the headlands is very simple and effective. By means of a lever on the left-hand side

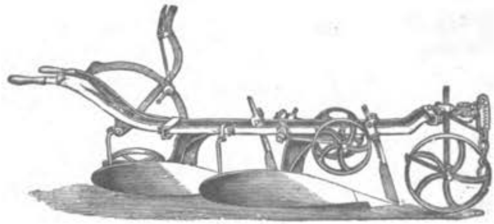


Fig. 31.

the handles, the land wheel on the left side of the plough, and a second wheel on the right side, which are both carried at opposite ends of a cross axle in the centre of the beam, are depresssd on reaching the end of the furrow, and by pulling the lever down the plough is lifted several inches above the ground. It can be turned on these two wheels with the greatest ease in either direction, and there is no wheel or other encumbrance between the beams.

By means of an adjustable clip, which can be set in any position on a circular arc, the depth of the ploughing can be adjusted from the handles. The beams can be adjusted, by means of two strong screws, to take two furrows, each 7 inches wide, and any intermediate width up to 12 inches, and from 4 to 9 inches deep.

By another improvement, which consists in raising the front body, the relative depths of the two ploughs can be altered. By means of this adjustment, which is very quickly done, the tops can be laid, and the finish or open furrows can be made as well as with an ordinary single plough.

This plough can be readily converted into a single furrow plough when required, and is then equally as efficient as an ordinary single furrow plough.

CHAPTER VI.

MULTIPLE FURROW PLOUGHS.

WHEN steam ploughing became so general in England, farmers, seeing three, four, or even six furrows rapidly turned over at a time by the steam plough, began to regard ploughing with a single furrow implement a slow operation, and the double-furrow plough has of late years been much used, especially in light land districts, where it will be found that the draught of such an implement when ploughing 6 inches deep is not more than 39 stones.

To give some idea of the saving in time by using ploughs which take two or more furrows at once the following table has been prepared.

Width of the Furrow-Slice.	Single Furrow Turnwrest Ploughs.	Swing and One-Wheel Ploughs.	Two-Wheel and Steerage Ploughs.	Two-Furrow Steerage Ploughs.	Three-Furrow Steerage Ploughs.
Width in Inches.	Miles in an Acre.	Miles in an Acre.	Miles in an Acre.	Miles in in Acre.	Miles in an Acre.
8	13	13¾	13¼	6⅝	4⅜
9	11½	12¼	11¾	5⅞	3⅞
10	10⅜	11	10⅝	5 6/16	3½
12	8½	9¼	8⅞	4 7/16	3

For the purpose of the calculation the length of furrow is taken at 220 yards, and the width of the plots or ridges at 22 yards.

With the headlands at 6 yards wide the horses have to travel $5\frac{1}{2}$ yards across each, and the same in turning. With ploughs having two wheels the horses travel

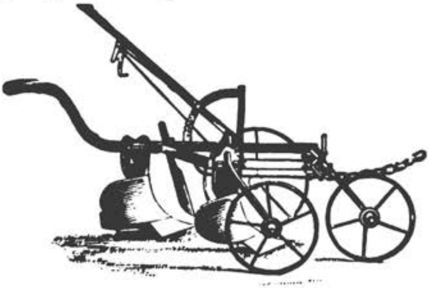


Fig. 32.

the segment of a circle from the end of the completed furrow to the commencement of the new furrow, and on an average travel $16\frac{1}{2}$ yards, thus saving about 8 yards at each turn, as compared with swing ploughs or single-wheel ploughs.

Howard's Self-lifting Light Multiple Ploughs.—Fig. 32 shows a two-furrow self-lifting plough. This implement is made extremely light, and is intended for

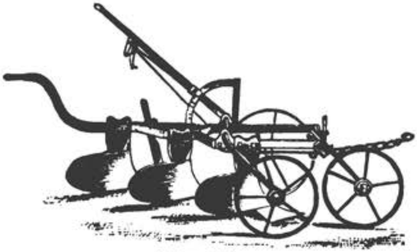


Fig. 33.

stubble ploughing, and for ploughing 4 or 6 inches deep on easy working land.

Fig. 33 represents an implement similar to the pre-

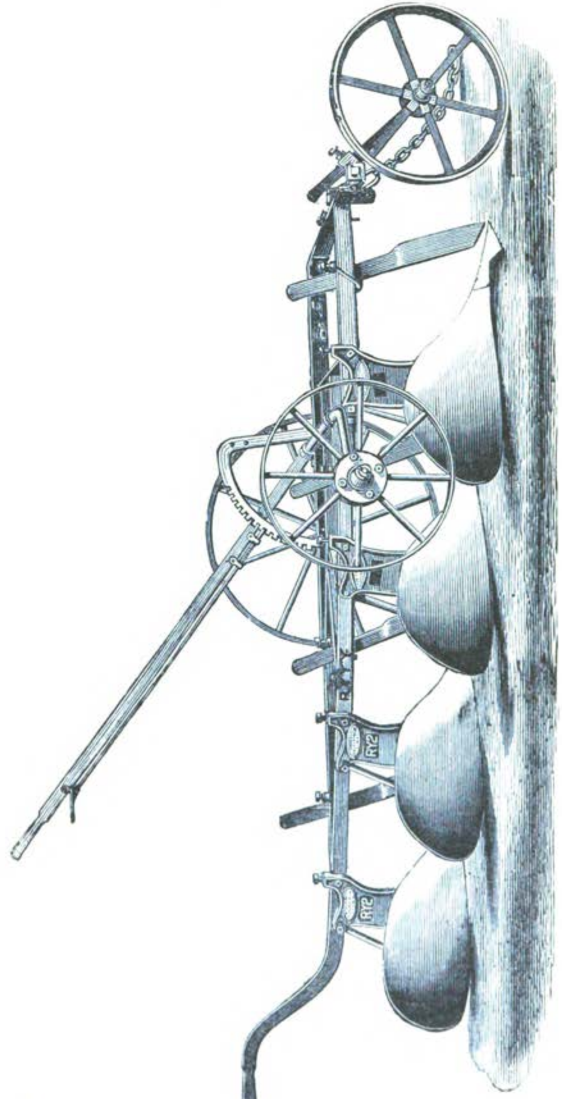


Fig. 34.

ceding, but made to take three furrows at a time. Large numbers of these ploughs are in use, and are highly approved wherever they have been introduced.

Hornsby's Four-furrow Plough.—This new implement, made for two, three, or four furrows, is introduced for light land districts where, owing to the scarcity of labour, it is needful to cultivate a large area in a short time. The three-furrow will plough 30 inches in width, each body taking 10 inches, and the depth may be adjusted as required. The four-furrow will plough 40 inches in width, each body taking 10 inches. The lever, when depressed, raises the plough out of the ground, so that it can be turned on its wheels at the headlands, and can also be readily conveyed from place to place.

CHAPTER VII.

GANG OR POLE PLOUGHS.

Gang or Pole Ploughs.—Within the short space of four years ploughing has undergone great changes on the large wheat-growing farms of America, and it must be matter of extreme interest to watch the result of such change. So recently as 1878 this splendid double-furrow plough, which figures so powerfully in our illustration, and which will become a most potent factor in future farming, came into existence, and its effect has been to reduce by several shillings per acre the cost of ploughing, and this operation is now performed at the low cost of 4s. 8d. per acre.

As the gang plough turns two or three furrows at a time, it saves the labour of an extra teamster or two, and this is a great economy, especially when wages are high. Where the land is suitable—that is, not too hilly, and free from large stones—the gang should be preferred to the single plough. There is some economy also in the power of the team, as it does not require the same force to draw a gang plough turning three furrows at a time, as would be necessary for three single-furrow ploughs. Again, a boy or an old man can ride and work it at half the wages of an ordinary ploughman.

For light or shallow work, such as giving a new surface to fallows, or turning over stubbles after harvest, it is invaluable, and several acres per day can be ploughed with a pair of horses.

Howard's New Riding and Self-lifting Gang Plough.— This (Fig. 35) is one of the very few English ploughs which provides a seat for the ploughman. We welcome it

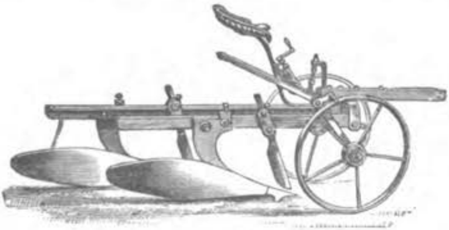


Fig. 35.

accordingly as a step in the right direction. We have trudged behind the plough many a day ourselves, and can well appreciate this invention. Instead of making lazy ploughmen, it will be the means of their doing more work.

There is need of this if our farmers are to hold their own against the American gang ploughs. And we say this without prejudice to the question whether the gang plough itself can compete with the steam plough. For working the American prairies we do not think the gang plough could hold its own against the steam plough, but that is not a point we need here discuss.

Howard's improved gang plough, being made with their patent self-lifting arrangement, are very easily worked. Instead of being lifted out of work by the ploughman, the lifting is done by the onward motion of the horses, and the ploughman by merely touching a handle brings into play a simple brake arrangement; this coming in contact with the wheels immediately lifts the plough clear of the ground, and when in this position the implement is balanced on its wheels and

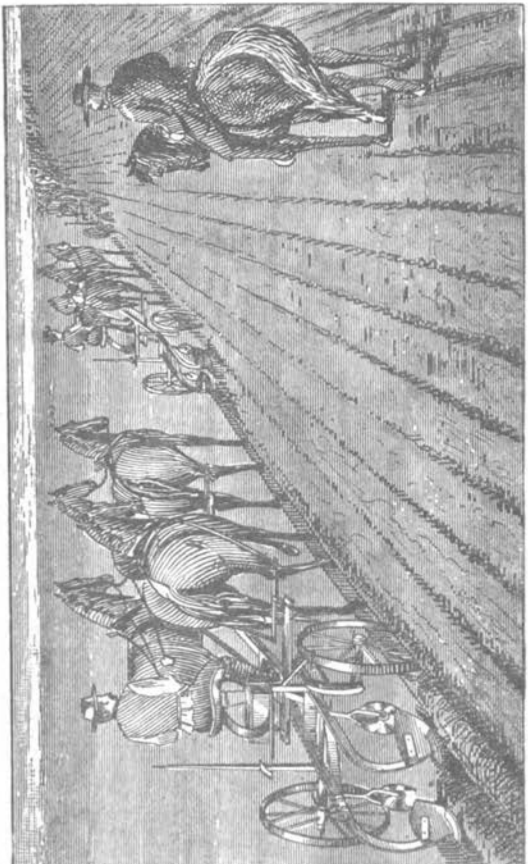


Fig. 36.

self-supported. By the employment of Howard's patent self-lifting arrangement all spring catches and racks are dispensed with.

The ploughs are shown raised as on the headlands, and appear nicely balanced, with the pole over the main supporting wheels. When turned in, the ploughman lifts the lever lying parallel with the pole along the sector-bar, when the ploughs drop into work by their own weight, share foremost. And when it is desired to lift the implement out of work, the ploughman, by means of a treadle and link gear, places the brakes on, and the forward pull of the team raises the implement on the wheels, as shown in the cut, the crank-arms in a vertical position. The land-wheel is adjustable upon its crank-arm, as shown in the cut, for regulating the depth of the furrow slice.

The ease with which ploughs mounted on large wheels are worked is now being generally recognised. With the same amount of power a larger breadth of land can be ploughed at a less cost and with less fatigue to the ploughman than on the old system.

The gang plough is drawn from whippletrees attached to the head of the beam, and the pole is free to rise and fall, thereby avoiding all pressure on the horses' necks.

CHAPTER VIII.

CULTIVATORS.

THE action of this implement is somewhat similar in principle to that of the harrow; but it is much more perfect, inasmuch as it stirs the soil to a much greater depth. Land is now frequently worked with this instrument without the use of the plough at all; and this perhaps is the most efficient way of cultivating land, off which turnips have been eaten, and preparing it for the barley seed. The manure left on the land by the sheep thus still remains near the surface; it is not buried at the depths to which it would be turned over, had the land been cultivated by the plough, as deep as it is by the cultivator. For breaking up stubble by steam power, the cultivator is always preferred to the plough. There is no implement leaves the ground in such a healthy state as this.

Coleman and Morton's Cultivators.—These celebrated cultivators have long possessed a world-wide reputation. They combine in one implement the cultivator, broadshare, and scarifier, and are at the same time extremely light in draught and easy to manage.

A great improvement has recently been patented by a new arrangement for the front wheels. In place of a single wheel and span iron, or crotch, which support the fore part of the implement, a pair of wheels is adopted, one of which is pinned to a steel axle, the other being loose. The axle is thus made to revolve in a suitable bearing of considerable length, entirely preventing any wear in the bosses of the wheels, and

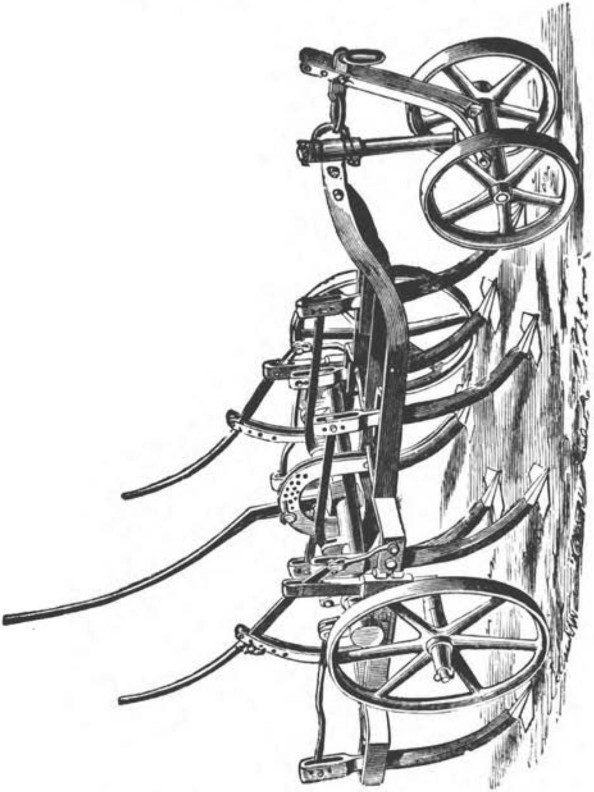


Fig. 37.

giving great steadiness to the implement. This arrangement also considerably lightens the draught.

Fig. 37 is an engraving of Coleman and Morton's cultivator for 4 horses, which will thoroughly pare or cultivate from 6 to 8 acres per day. It has 7 prongs, and is fitted with side levers, by means of which the implement may be kept level with its work, although used on hilly ground or with one wheel running in the furrow. It will be noticed that it has shares cutting behind the wheels, so as to cut up the wheel tracks.

A lighter implement with 5 prongs is adapted for being worked by 2 horses.

The centre lever (Fig 37) regulates the depth, the pin being always kept in front of the lever. It is also used to raise the prongs out of work at the land's-end before turning.

In the prongs there are two sets of three bolt-holes. The top holes are for very deep work, the middle holes for general work, the bottom holes for paring in very dry, hard land. Care should be taken that the holes used in each of the two sets correspond.

The shares are fastened to the prongs with wooden pegs. By the use of various pattern shares sent out with the cultivators, these implements will perform any kind of work for which a cultivator, grubber, or scarifier can be required. There are shares for hard, dry land, for wet and foul land, for breaking up and cleaning; and winged or double-breasted shares for more fully lifting up the soil and leaving it loose.

Combined Plough and Cultivator.—This implement is used either as a four-furrow plough or as a cultivator. It is admirably adapted for use on light land, and also for covering seed when sown broadcast.

The breasts can be readily removed and the prongs arranged as in the ordinary cultivator.

The price of the implement, complete as plough and cultivator, is £11 10s.

Drag Cultivator.—This implement has recently been constructed to meet a special want in the cleaning and

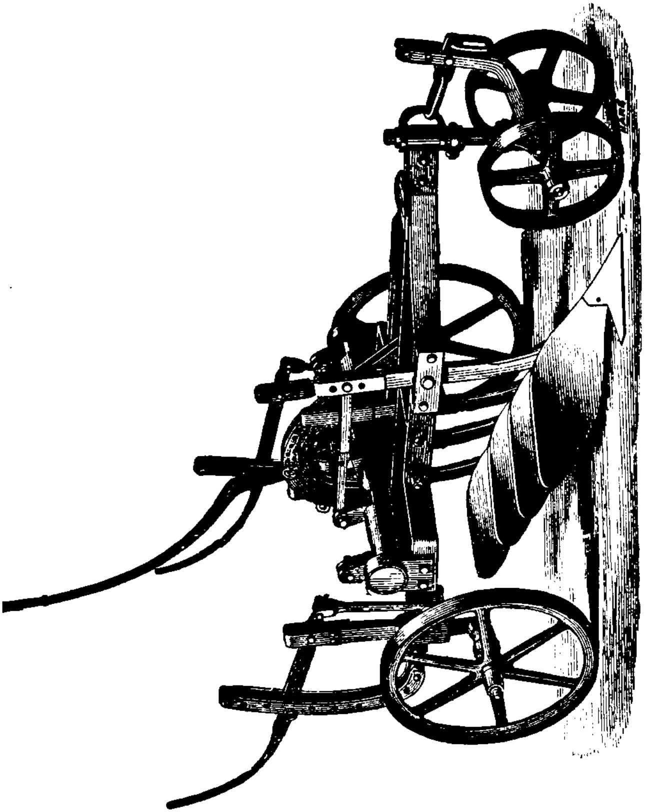


Fig. 38.

preparation of land for seed, and is most effective for that purpose.

Instead of merely dressing down the loose surface, filling up the hollows, and leaving almost untouched the solid parts of the furrow slice, as is often the case with some of the drag harrows in use, it cuts through the whole of the work to the depth ploughed, bringing up weeds and "couch," and making a perfect seed-bed.

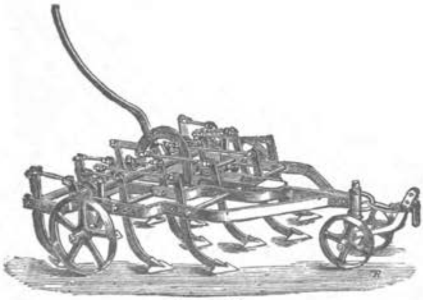


Fig. 39.

With 13 prongs, and width of cut 5 feet 6 inches, the price of this implement is £9 10s.

Clay's Cultivator.—The advantages of Clay's cultivator are well known. The combination of a broad-share, cultivator, grubber, and drag harrow in one frame, in conjunction with the patent relieving action possessed by these

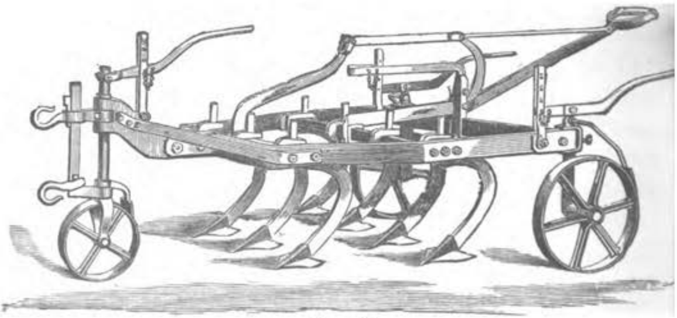


Fig. 40.

cultivators, may safely claim rank amongst the most approved implements of modern agriculture.

Although a relieving motion may not be much required when broadsharing, yet a lifting-out action gives considerable advantages, particularly when turning the ends of the lands or "bouts." In stony ground more especially, the certainty and ease with which the tines of these instruments are liberated will enable the attendant to prevent many accidents happening, by instantly taking the lever out of the notch when he hears the grating noise peculiar to thin soils, an operation impossible with most implements, from either the want of a releasing motion altogether, or because of such motion being forwards (against the work) instead of backwards. These cultivators, moreover, are un-

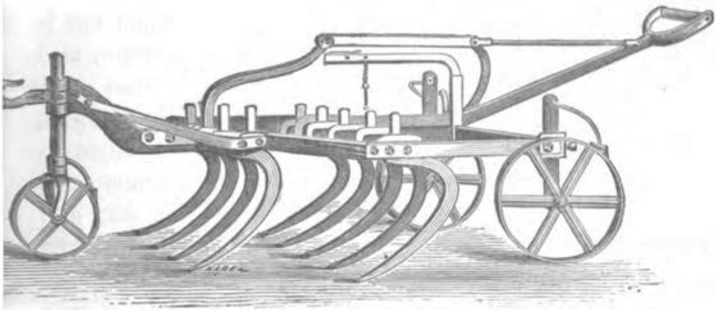


Fig. 41.

commonly easy of draught, so that in no case is there any disadvantage.

When used, however, as grubbers or drag harrows, the advantage of this relieving motion is found to be very considerable.

The cultivator goes on three wheels, which are chiefly required to regulate the depth of work. Upon these is fitted a frame, within which strong bars work in carriages, being partly moved round at pleasure by the action of the lever and arms. The tines are fixed upon these bars with steel wedges. By removing these wedges the tines can be taken off the bars, consequently their number can be increased or diminished at pleasure, and thus be made to suit any kind of work, a greater number being required for working barley and fallow land than for stubbles.

Fig. 40 shows the cultivator fitted with seven tines, and with levers to wheels, fallow coupling-hook, patent catch and broadshares. In Fig. 41, the implement is shown with nine drag-teeth, which require only sharpening the same as harrow-teeth. Fitted as in Fig. 41 the implement costs £12; and fitted as in Fig. 40 the cost is £9 9s.

Clay's Chisel Harrow Cultivator.—This implement is well adapted for spring and autumn cultivation, and will be found most useful for working stubbles after they have been broken up by the cultivators or ploughs, and for stirring barley and fallow land. Our illustration, Fig. 42, shows the position of the various parts when relieving the implement from weeds, &c., and when turning at the ends, and also when travelling on roads.

The teeth or tines being fixed with steel keys upon revolving bars make them exceedingly easy of removal for repairs and alterations to suit foul or fine soils. The method of raising the teeth out *backwards* by the lever is the same as in the cultivators.

The alteration in the depth is somewhat different to the cultivators; each side wheel, being mounted on a levei with quadrant and pin, is easily altered during the progress of the work. A considerable advantage is obtained by the wheels being altered *separately*, as this arrangement enables the workman to drop a wheel into a furrow and adapt it to hill sides and other irregularities, and yet allow the implement to remain level—a thing impossible with chisel harrows altered by the old lever, quadrant, and rack acting on both wheels at once. The raising of the teeth backwards, the same as in the cultivators, gives to this harrow all the advantages of those celebrated implements, allowing the attendant most easily to release it at the ends when turning, and to relieve it when choked with weeds, &c., on foul land; whilst the ready method of altering the number of teeth (without screws or clamps), as well as taking them out for repairs, does not require further remark

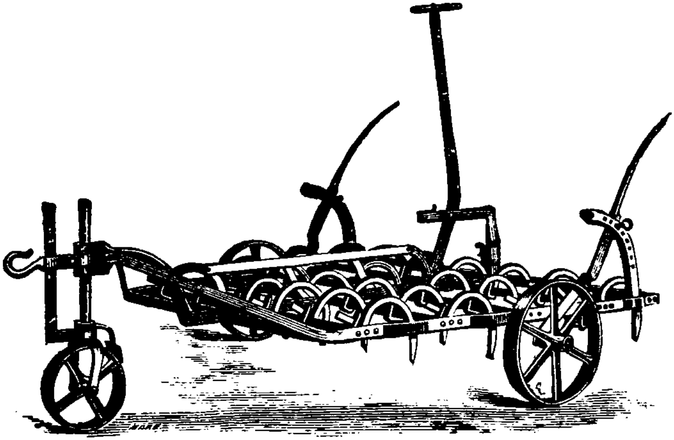


Fig. 42.

to show the advantage of that arrangement. The teeth are made with chisel points sharpened the same as ordinary harrow-teeth, and with tines having cast-steel points on them fixed on the bars similar to those on Clay's cultivators, so that no smith's work will be required for sharpening. The harrow can be made any width to suit purchasers.

The harrows are fitted with Clay's patent movable catch (Fig. 42), by which the pitch of the points may be altered so as to give the implement more or less hold of the soil, similar in effect to that of a lever neck in a plough. By loosing the two nuts on the side of the catch under which the main lever fits, the catch may be raised and fixed again there by nuts. This will throw down the points of the teeth or tines, and cause them to enter the ground better when the surface is hard.

The Bentley-Howard's New Patent Riding and Self-lifting Cultivator, for working with horses, is shown in Fig. 43. The implement can be instantly raised out of work for clearing it of rubbish, or for turning purposes.

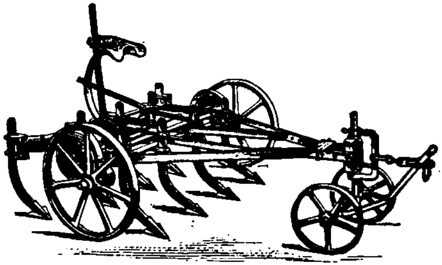


Fig. 43.

The Bentley Cultivator.—Mr. Boby, Bury St. Edmunds, is the maker of this justly celebrated implement for autumn or spring cultivation.

It has precisely the same form and action as a four-furrow plough in the mouldboards or breasts, the shares being so arranged as to ensure the whole of the ground being thoroughly broken up, completely disintegrating the soil to any reasonable depth, and leaving the surface so that the action of the harrows effectually destroys all grass and weeds. One operation on the stubbles after harvest will be found equal to two or three with the common scarifier or broadshare, while the draught is very considerably lighter.

For pulverising stiff land after turnips have been fed off, it will save a ploughing at half the cost; and is superior to rippling or a cross tillage, making a better seed bed for the barley crop.

It can be used with great advantage in summer in preparing for turnips, as it effectually destroys thistles and annual weeds without letting in the drought or leaving a hard pan under the surface.

The price of the cultivator is £8 10s.

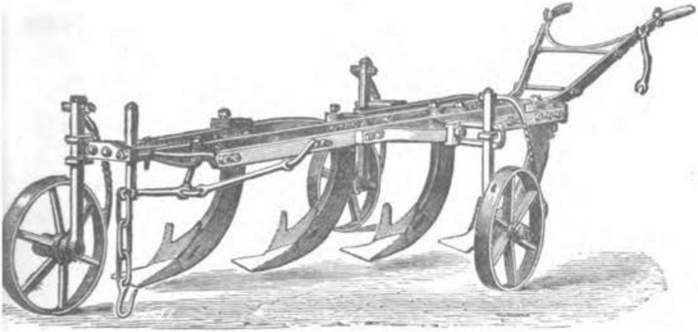


Fig. 44.

Craig's Circular Grubber.—This patent three-tined circular-frame grubber or cultivator is on an entirely new principle. It has a circular frame, with three peculiarly twisted steel coulters, all turned to one side; to these are attached prongs for thoroughly turning up the weeds, pulverising stiff land, and keeping a clear furrow. It is also capable of being adjusted to the nature of the ground, and by a very simple arrangement can be made to expand from 18 to 38 inches, thereby being available if necessary as a drill-hoe or cultivator. A connecting rod, wrought by a pivot, affects the tines, so that at whatever width they are wrought they are always on the same angle as the beam.

The grubber, which is now extensively used, is manufactured by Messrs. G. W. Murray & Co., Banff.

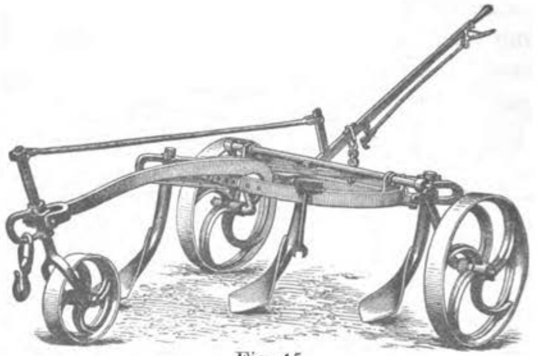


Fig. 45.

The price of a two-horse grubber varies from £7 10s. upwards, according as it is intended for light or heavy land.

Craig's Patent Digger.—This implement, which is

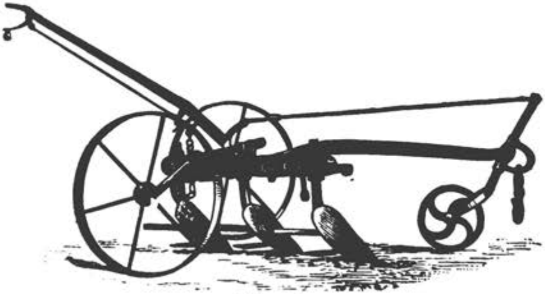


Fig. 46.

also manufactured by Messrs. G. W. Murray & Co., is specially adapted for breaking up stubbles and for cross ploughing.

It has a most convenient frame, combining lightness with strength, is fitted with two steel shares with digging breasts, which can be raised or lowered to turn down the upper soil to any required depth. By a special arrangement the wheels are placed so that none of them run on the cultivated land.

On very stiff soil the first tine can be taken out, when a pair of light horses can draw it with ease, thoroughly breaking the soil from bottom to surface. By taking off the digging prongs and fixing others on the same place, the work done will be similar to that done by Craig's circular grubber.

The wear and tear of this implement is 50 per cent. less than in the ordinary plough.

Mr. John Ross, Meikle Tarrell, Ross-shire, writes: "I have had two of Craig's diggers for some time, and am very much pleased with them. They break up barley land after sheep far better than any implement I have tried. One pair of horses do over double the ordinary plough work, without overtasking the horses. They leave a capital seed-bed, saving almost two tines of the harrow. They are simple in construction and easily managed."

The price of this implement is £10.

CHAPTER IX.

HARROWS.

HARROW, in old English *hyrwe,* meaning "to tear up."

In modern husbandry the harrow is made use of for three purposes: 1, to refine and pulverize the surface of ploughed land; 2, to clean land that has been ploughed or cultivated, by bringing weeds to the surface; and 3, to cover the seed.

Very many different kinds of harrows are employed to effect these operations, and it will be our duty to bring forward and notice in detail the principal of them.

The modern harrows are, as a rule, entirely constructed of iron; and the tines are so arranged that each of them cuts a fresh track of its own. Harrows that have the teeth working at right angles to the frame are also being discarded in favour of curved teeth, or, in some cases, even twisted teeth.

Howard's Zigzag Harrows.—These harrows have stood the test of many years' experience, and they still remain unrivalled. They are strong, durable, and thoroughly adapted for all kinds of work. The tines, which are all steeled, cut a separate track at a uniform distance, and are fitted into the frames in the simplest and most secure manner, and by means of a guard to the nuts they are effectually prevented from working loose.

The four-beam harrows, as in Fig. 47, with 5 rows of tines, and covering $7\frac{1}{2}$ feet of ground, weigh 1 cwt., and cost, with whippletree complete, £2 17s. 6d. A larger and heavier size of

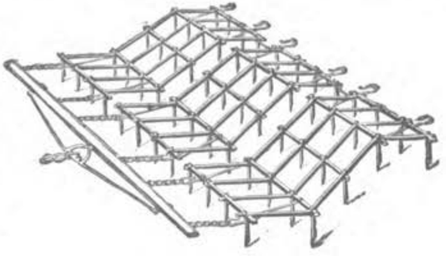


Fig. 47.

the same harrows, covering 10 feet in width, weigh $2\frac{1}{4}$ cwt., and cost £4.

Howard's New Patent Simplex Harrows.—This new harrow promises to be one of the most durable and efficient ever produced. Whilst possessing all the good qualities of Howard's zigzag harrows, they may be said to excel them in several important points of construction.

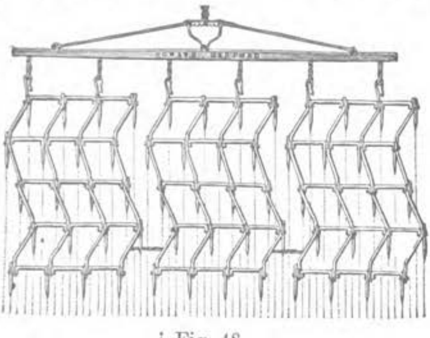


Fig. 48.

The chief novelties in the new patent simplex harrows are that they are made of double-flanged iron—I—which combines lightness with great stiffness and strength.

The tines, which are solid steel, are so formed that the ordinary cross-bars are dispensed with, each tine forming its own cross-bar, and fitting into a wrought-iron block or clip. These blocks or clips fit into as well as embrace the double-flanged bars, and each tine is held securely in position by a bolt passing through the tine, the block, and the clip.

This new method of fastening adds strength to the bars as well as to the tines, and this just at the point where other harrows are most liable to become strained or broken. It also gives absolute security against the tines working loose, and these, when required for repair, can be quickly removed and replaced.

No tubes or cast-iron pieces are used in the construction of the new simplex harrows.

Ransome's Patent Jointed Harrows.—In these har-

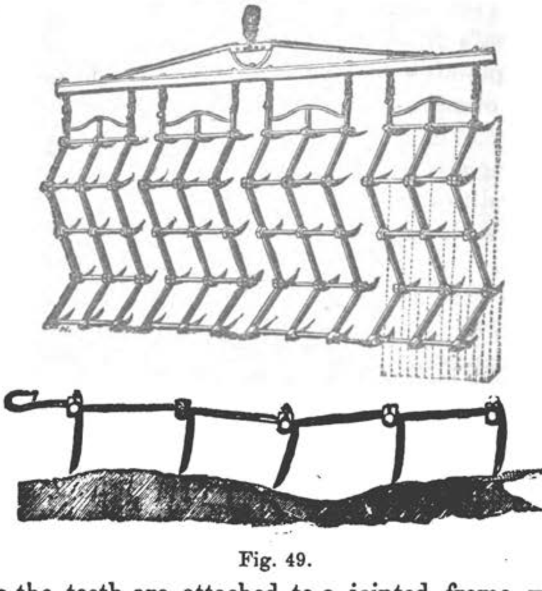


Fig. 49.

rows the teeth are attached to a jointed frame, which allows them to follow all the irregularities of the soil, as shown in Section A. The teeth being allowed to play in this manner, gives the whole harrow a much freer action, and helps to pulverize the soil. They are well adapted for breaking down clods, and for bringing to the surface and collecting weeds, rubbish, &c. They are made entirely of wrought and malleable iron, in two different weights, and two, three, or four to a set.

Coleman & Morton's Improved Jointed Harrows (Fenton's Patent).—These harrows are constructed

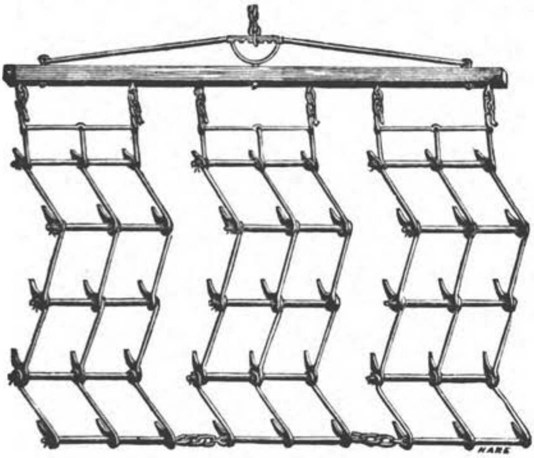


Fig. 50.

with joints at each cross-bar, by which they readily accommodate themselves to an inequality of the land, with a freedom of action which increases their efficiency in breaking down clods, in bringing to the surface all weeds, and in thoroughly pulverizing the soil at one operation.

They can be folded singly, as shown in Fig. 51, for convenience in travelling.

Howard's Drag Harrows.—These harrows are for thoroughly cleaning and pulverizing the soil after ploughing. They are made with long curved teeth, on the well-known zigzag principle, and are furnished with handles, by which convenient arrangement the tines can be pressed into the ground, or lifted out to clear them, as occasion may require. They are used with three or four horses on rough fallows, and for much

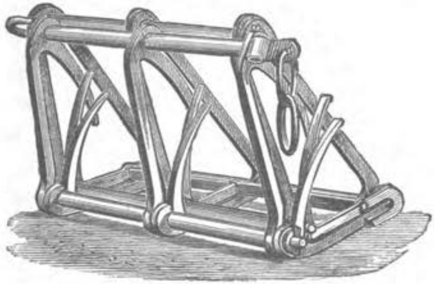


Fig. 51.

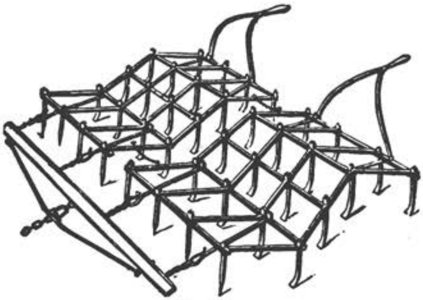


Fig. 52.

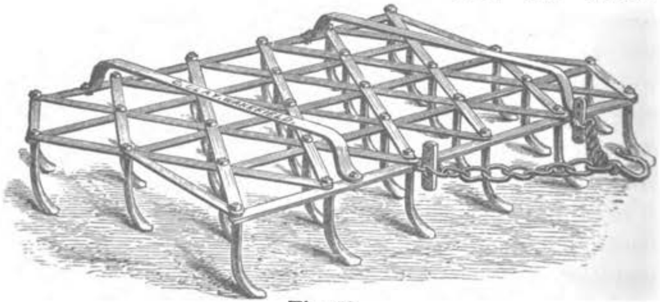


Fig. 53.

work of this kind are preferable to scarifiers or cultivators.

Clay's Improved Chisel-tooth Harrow.—This harrow is now much used for working barley and fallow land, making a fine seed-bed, and is a most useful implement to work after the plough or cultivator. It is made in two sizes, the larger covering 6½ feet in width and the smaller 5 feet.

Howard's Self-lifting Wheel Harrows.—These implements will be found very serviceable, both as drag-harrows and as light scarifiers or cultivators. They possess an advantage over the ordinary drag-harrows in being mounted upon wheels, which, whilst diminishing the draught, allow of ready adjustment for harrowing the land deeper or shallower as may be required. When the implement arrives at land's end, upon the driver releasing the catch the harrow, by the forward movement of the lever, is at once lifted clear of the ground, for, as will be seen from the engraving, the draught-chain is attached to the arm of the lever. The self-lifting arrangement has this advantage, that the harrow can be raised and cleared without stopping the horses. The tines are fitted with loose steel shares, which can be readily replaced when worn.

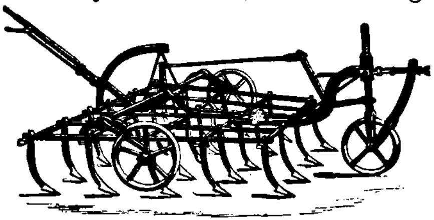


Fig. 54.

Clay's Improved Drag Harrows on Wheels.—This form of harrow is well adapted to general requirements, especially when the soil is not too full of rubbish.

The addition of wheels to drag harrows makes them much lighter in draught, whilst at the same time the improved form of leverage, together with the simple adjustment of the depth by rack and pin, makes these

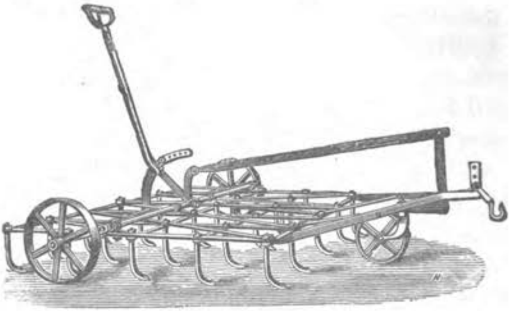


Fig. 55.

harrows most efficient spring and autumn field implements.

Norwegian Harrows.—Experience has proved that there is no other harrow equal to this implement for pulverizing a piece of rough strong land after it has been broken up by a cultivator or cross-ploughed. For harrowing immediately after ploughing, it breaks and pulverizes the furrow, leaving 3 or 4 inches depth of fine mould beautifully prepared for seed; it saves the use of heavy and middle-sized ordinary harrows, the small seed harrows being sufficient. Again, while other pulverizers consolidate the land, and harrows leave the clay in large lumps, this implement pulverizes but does not consolidate; and it prepares the roughest land, whether wet or dry, without clogging.

Clay's Improved Norwegian Harrow is represented in Fig. 56. By the improvements now introduced, the draught has been so far reduced as to bring it within the power of three horses, whilst at the same time the leverage arrangements are much simplified, enabling the man to raise the implement easily out at the ends, thus further reducing the strain upon the horses. The improved forms of the spikes makes it a most efficient clod-crusher and pulverizer, and by the lever and rack the three rows of spikes can be regulated to any height

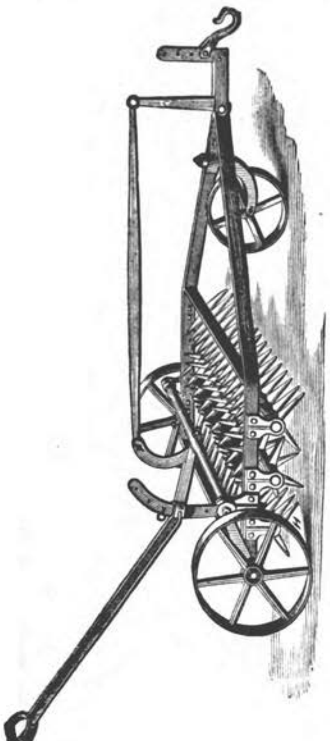


Fig. 56.

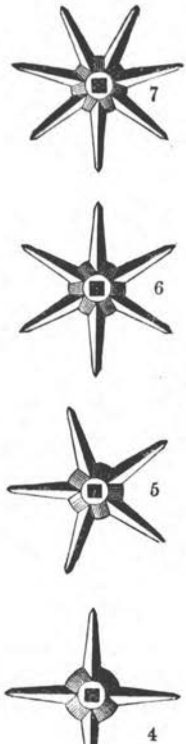


Fig. 57.

from the ground, so as to press either heavily or lightly upon the land surface as may be required. The harrow is usually made 5 feet wide.

Mr. Clay has lately brought out the following new patterns of stars to fit the Norwegian harrows, with a view to meet the varied requirements of all kinds of soils. No. 4 star is adapted for very strong clay soil, with or without stars in it. No. 5 is for strong rough work. No. 6 for medium soils. No. 7 for light land. A very good and useful combination for general work is made by placing Nos. 4, 5, and 6, in the first, second, and last rows respectively.

Howard's Steel Disc Riding Harrows.—These harrows, Fig. 58, are very effective labour-saving implements,

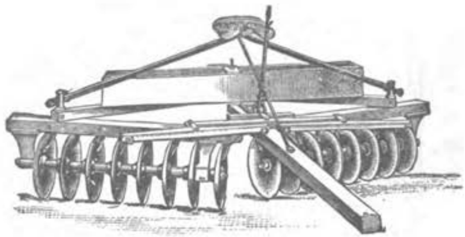


Fig. 58.

and contain some important improvements, which add to their efficiency and durability. The gangs of discs are connected by a universal joint with a bracket sliding on the pole, which allows the discs to be worked at any desired angle, as well as to rise and fall with the irregularities of the land. The discs are dished or concave in shape, and as they revolve they lift, and to some extent invert, the soil to the depth they penetrate.

For crossing ploughed land, for producing a thoroughly pulverized seed-bed, for covering seed sown broadcast, for cleaning summer fallows, and for stirring stubbles, these disc harrows are most useful implements.

The seat is now placed over the back of the pole, which is balanced by the weight of the driver, who is thus well-placed behind the discs, and the lever is made to form a rein guide, as well as a safety-guard in front of the driver.

Howard's Steel Chain Harrow is a great improvement upon the ordinary chain or link harrow. It is not liable to get out of order, the points of the tripods being immovably fixed to wrought-steel rods. The points of the tripods are chilled all over, and are longer on one side than on the other, and, being rounded off at the back, the harrow is rendered as efficient for

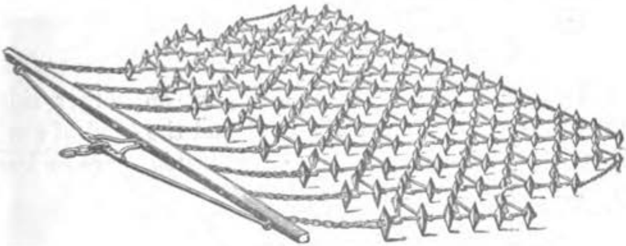


Fig. 59.

arable land as the common chain or link-harrow, while at the same time its superiority as a grass-land harrow is fully maintained. These harrows will do as much in going over a field once as the ordinary chain or link-harrow will do in three times. When used upon arable land, the harrow should be drawn the reverse way.

The price of a two-horse harrow, 8 feet wide, is £3 10s.

Howard's Flexible Grass Harrows.—These harrows act with splendid effect, both on arable and pasture land. They are constructed of cast spiked tripods connected by wrought-steel links in such a manner that a new tine or link can be attached by the driver in the field. The points, which are chilled at both ends, are longer on one side than on the other, and are rounded off at the back. The harrow may therefore

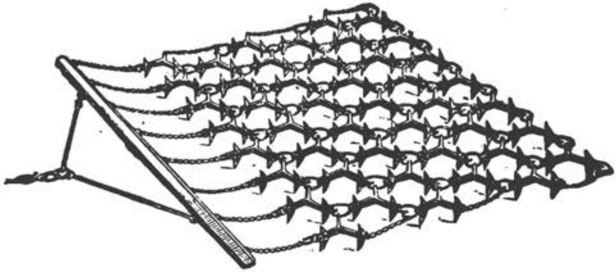


Fig. 60.

be worked backward or forward, or on either side, according to the state of the land and the kind of work to be done, the ground being penetrated more or less, as may be desired.

CHAPTER X.

ROLLERS, CLOD-CRUSHERS, LAND-PRESSERS.

The roller is an implement used for breaking hard clods expeditiously, and for smoothing and compressing the surface of land, either when in tillage or when in grass.

As weight and durability are alike essential in an implement of this kind, rollers are now generally constructed of cast metal. They are made in different sizes, from 13 to 26 inches in diameter, and from 6 to 8 feet wide, to be worked by one or more horses.

The roller should be in two or more sections, as then it is not only less severe on the horses when turning at the end of a field or ridge, but avoids the danger of tearing up part of the ground and crop. A large roller in one section in turning short does not move round its axis, but is dragged along. When in sections, each of them in turning moves round its own axis, the one rolling forward whilst the other rolls backward. By this means the surface of the land is not broken, and the young plants are left uninjured.

Coleman and Morton's Land and Grass Roll.—This roll (Fig. 61) is a strong and well-made cast-iron implement, with straight spindle, and having the cylinder cast in two sections. It is especially recommended for pasture land. Its width is 7½ feet, and the diameter 13 or 20 inches.

Coleman and Morton's Burley and General Purpose Roll.—Fig. 62 shows a light but strong implement,

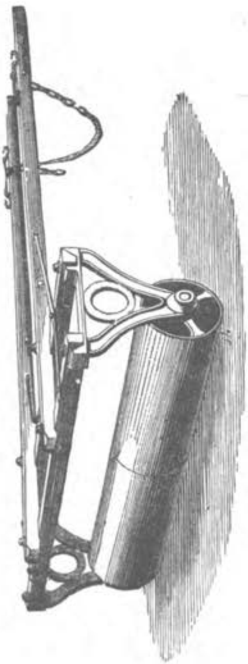


Fig. 61.

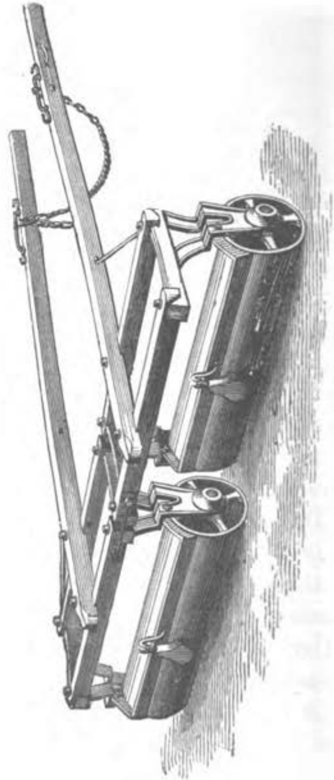


Fig. 62.

well suited for barley rolling, &c. It is adapted for land either in stetch or on the flat, and having one cylinder in advance of the other, the whole surface is covered. The cylinders are made either of cast or wrought iron as preferred, and are fitted with loose boxes. Each roll is furnished with scrapes, as shown in the engraving.

Howard's Improved Sectional Field Rollers.—These rollers are constructed with a number of short cylinders, plain on the face, but with inside ribs, to give great strength as well as durability to the edges. Each cylinder revolves independently upon the axle. The frame is made of wrought angle iron, the bearings of hard wood, and every part is very strong and durable. In working the same result is obtained as with the ordinary

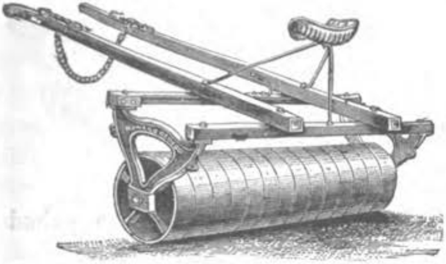


Fig. 63.

plain roller, made in two or three parts, but the sectional roller turns more easily at the ends, and with less disturbance of the soil.

Howard's Fluted Roller.—This (Fig. 64) is an improved form of Cambridge's press wheel roller, and is constructed of strong cast wheels with wedge-shaped edges, revolving independently upon the axle. The frame is made of wrought angle iron, the bearings of hard wood, and every part is very strong and durable.

The great advantages of these rollers are that by rolling land planted with wheat or other crops the surface is levelled or smoothed—a good preparation for loose hoeing—and stones and other obstacles to the use of the scythe or reaping machine are removed. The consolidation of the soil effected by these rollers tends to keep in the moisture and to check the growth of weeds, and the soil being compressed around the roots or seed the plant thrives better. The ravages of the wire-worm and grub are also checked, and the crops are not so liable to be laid as upon unrolled land. These rollers are made with a pole instead of shafts

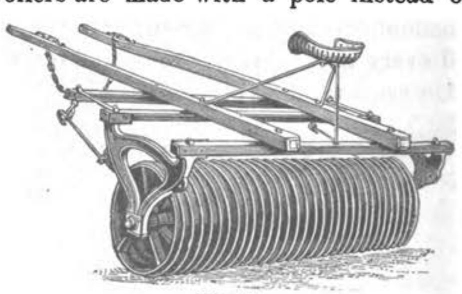


Fig. 64.

for countries where the animals are yoked in this fashion.

Crosskill's Clod Crusher.—This well-known self-cleansing implement, with patented improvements, is entirely free from any loose lateral motion of the discs. It consists of cast metal discs or roller-parts, placed loosely upon a round axle, so as to revolve independently of each other; the outer surface of each roller-part is serrated, and has a series of side-way projecting teeth, which act perpendicularly in breaking clods. Each alternate disc is made of larger diameter than the rest, and the size of the holes in the large discs is correspondingly increased, so that both the large and small discs touch the ground, and none of them can rise up over a clod without lifting all the rest. The difference in the size of alternate discs causes them to revolve in different circles, and no land, however moist or sticky, can clog them up or cause them to become a smooth solid mass.

When taken to the field a hole is dug under each travelling wheel until the roller parts rest upon the ground, and the wheels can then be taken off. The same method must be used to get them on when required.

Fig. 65.

Crosskill's improved clod crusher can be advantageously used for the following purposes:—

1. For rolling corn as soon as sown upon light lands, also upon strong lands that are cloddy before harrowing.

2. For rolling wheats upon light lands in the spring, after frosts and winds have left the plants bare.

3. For crushing clods after the turnip crops, to sow barley.

4. For stopping the ravages of the wire-worm and grub.

5. For rolling barley, oats, &c. when the plants are 3 inches out of the ground.

6. For rolling before sowing clover again in autumn, and in the winter or spring whenever the clover plant has a tendency to throw out.

7. For rolling grass and mossy lands after compost.

One of these implements, covering 5 feet of ground, and with discs 2 feet in diameter, costs £14; covering 6½ feet of ground £18.

Land Presser.—This implement (Fig. 66) is intended to follow the plough and press the land in the

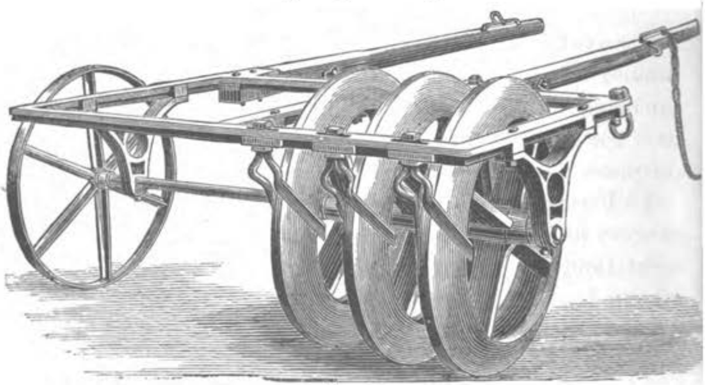


Fig. 66.

furrows before sowing wheat, oats, &c. It is particularly useful for preparing lea ground for corn, and in breaking up rough new land for immediate cropping, even when it is intended to use the corn-drill; but it is of value even in turnip land or in stubble ploughing. By its use a firm seed-bed is obtained, and the ravages of wire-worm are much checked.

Fig. 66 is an engraving of Reeves' Improved Land-Presser. It is made with two or three wheels to suit the number of ploughs. The two-wheel presser costs £7 10s., the three-wheel presser £9.

CHAPTER XI.

DRILLS.

In sowing it is very desirable that the seed be distributed with regularity over the surface and in the quantity which experience has found most desirable for each kind of seed. It is also desirable that the seed be deposited at precisely that depth in the soil at which it will be most favourably circumstanced for germination. Now machinery, by the regularity and certainty of its action, is eminently adapted for the purpose of placing seed at the right depth and in proper quantity. It is not therefore merely as a labour-saving agent that sowing machines are useful, they accomplish the work with a perfection that is not possible for labour unassisted by their means to attain. It is found that seeds sown in drills yield a crop more economically than when the seeds are sown broadcast. The machines which are employed in sowing are now therefore generally adapted for depositing the seed in drills. These machines are themselves technically called *drills*, in consequence of the object for which they are employed.

"A good drill," says Mr. Pidgeon, "should sow uniformly the same quantity of seed, whether travelling on level ground, along the side of a hill, or up and down hill. It should adapt itself not only to all kinds of seeds, but to all conditions of seeds. The regulation of the quantity to be sown per acre, the shape of the coulters, and the steerage of the machine, are all matters of importance, but even sowing is the most important of all.

"The last trials of corn and seed drills, conducted by the R.A.S.E., took place at Bedford in 1874, and clearly evidenced that this class of machine is still capable of considerable improvement. Equal distribution of seed to each furrow was the point on which the judges principally insisted, and great was the surprise of some exhibitors when they saw canvas bags hung on the seed-tins of their machines, and their contents weighed after a run of 200 yards. This simple test, however, disclosed some remarkable irregularities. The difference between the quantity of oats received by two furrows was in one case at the rate of 40 lbs, or a bushel an acre, while even the first prize machine varied as much as 7 lbs. an acre.

"Almost all the drills exhibited at Bedford were fitted with the well-known cup delivery, which is now universal throughout England and the Continent. Theoretically speaking, cups should be perfectly regular in their delivery on land, for if they are alike in capacity, and are all set at the same angle to the diameter of the cup-wheel, they cannot fail to discharge exactly the same amount of seed with every revolution of the wheel-spindle. Practically, however, it is a difficult matter in this class of work for the maker to set every cup rightly, and every hopper almost in contact with the cup-wheel, while the stems of seed-cups are easily bent, and the tin hoppers easily misplaced in working."

The far-famed "Suffolk Corn Drill" of Richard

Garrett and Sons is represented in Fig. 67. The makers have lately introduced several important improvements in the construction of these machines. They are now adapted for every part of the world, and to deposit any quantity of corn and seed. The number and relative

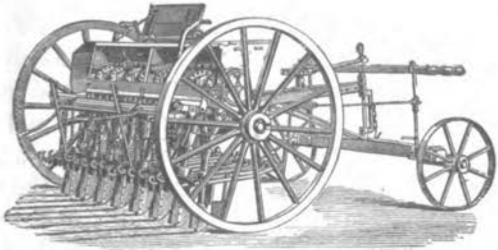


Fig. 67.

width of the rows can be arranged at will, and with the least possible trouble. The weight of the drills has also been very considerably reduced, and at the same time the strength and durability increased.

The engraving represents a side view of the drill,

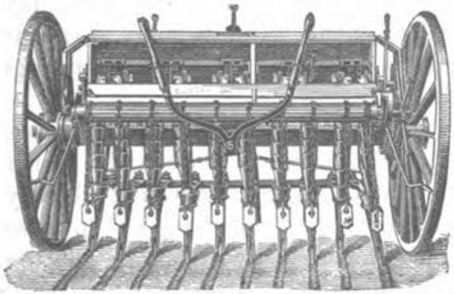


Fig. 68.

showing it with fore steerage. With this steerage, which acts as a fore carriage to the implement, a man may keep the rows of corn perfectly straight and equidistant by holding the steerage handle, and keeping the small fore wheel in the track of the former large one. With a little practice this is very easy, and the expense of using the steerage will be amply repaid by the perfect regularity of the rows throughout the field, which greatly facilitates the use of the horse-hoe in cleansing the crop.

Garrett's Swing Steerage Corn Drill is shown in Fig. 68. It has been specially designed to meet the requirements of large occupiers in "mixed soil" and light lands. The principal features in this drill are: ample height and breadth of travelling wheels; the great capacity of the seed-box, a point of importance where the fields are large; lightness of framework, levers, and all details; ample steerage room and leverage, by means of which one drillman can with care ensure accurate work, to be followed in time by the horse-hoe; the facility with which the seed-boxes can be removed, and the frame and wheels transformed into Garrett's improved patent horse-hoe.

The "Nonpareil" Corn Drill of Messrs. Smyth James and Sons, Peasenhall, exhibits many of the most recent improvements in drills. Fig. 69 is an engraving of this drill.

In the "Nonpareil" drill, the newly patented hoppers do not require to be removed when the cup barrel has to be taken out. The great advantage hereby attained will be evident to all who have had to do with drills, as it avoids the necessity of taking out the hoppers when changing the cup-wheels, thus doing in *two minutes* what formerly occupied half an hour, and at the same time it does away with risk of hoppers being accidentally torn out by the cups, as in case of anything now by accident coming between the hoppers

and the cups the hopper shoots are merely thrown back.

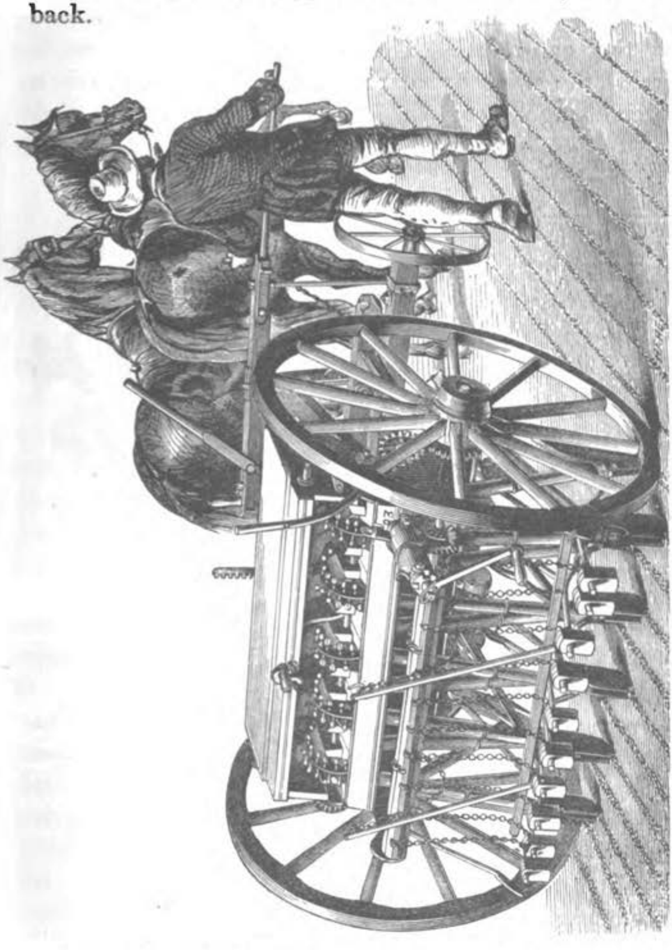


Fig. 69.

At A, Fig. 70, the shoots are shown as turned back ready for the barrel to be taken out, and B in position for drilling.

The newly patented support bearings fall down by releasing a catch so as to allow instantaneous removal of the cup-barrel. The newly patented cog-work avoids the necessity of raising or lowering the box when changing cog-wheels, is exceedingly simple, and

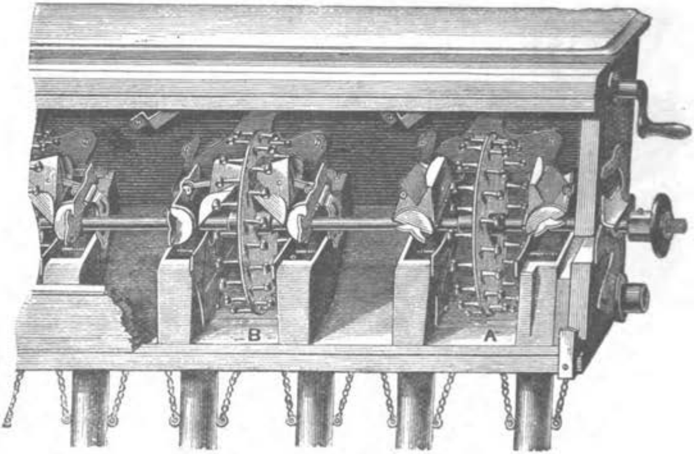


Fig. 70.

gives a much larger range of seeding than formerly attainable with a larger number of cog-wheels.

In the new gearing and drop bearing, Fig. 71, the cog-wheel 22 is attached to the cup-spindle, and when it is replaced by a larger or smaller wheel, the radius lever which carries the intermediate wheel, N P 3, is moved to the left or to the right so as to gear properly.

Hand Seed Drill.—Boby's little drill, Fig. 72, is recommended for patching blanks or misses, where the turnip has been destroyed by fly, &c., and will be found invaluable for use amongst all cultivated crops. By means of a thumb-screw it is readily adapted for sowing wheat, barley, turnip, mangold, onion, carrot, cabbage, in fact, all kinds of farm and garden seeds. The seed is deposited in a hopper, which can be had of

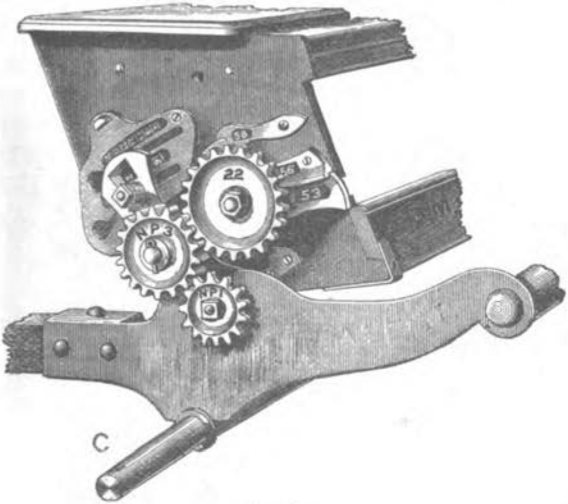


Fig. 71.

various sizes, and by simply pushing the drill along the ground the travelling wheel gives motion to a slide at the bottom of the hopper, and the seed falls through a tube situated behind the coulter and drops into the furrow. The seed, on the other hand, ceases to run through the moment the drill is lifted off the ground.

Fig. 72.

A very similar implement has for many years been manufactured by Mr. Le Butt, and is extensively used in gardens and elsewhere.

Clover and Rye Grass Drill.—The practice of drilling

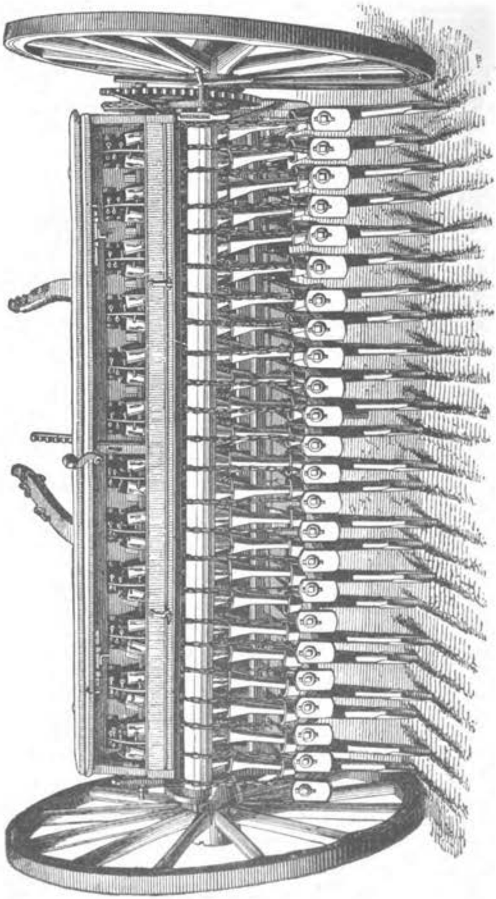


Fig. 73.

clover and rye-grass is now adopted by many agriculturists, it being considered by the advocates of this system that a much better, more regular and certain crop is obtained. A drill for this purpose is manufactured by James Smyth and Sons, Peasenhall, on the cup principle, to drill the rows as near as 3½ inches apart, and wider distances by taking out one or more levers. The same machine can be adopted for drilling corn and turnip and mangold seed.

Turnip and Manure Drills.—Garrett's Turnip and Mangold Seed Drill, fitted with Chambers' Patent manure barrel and scrapers, which can also be made

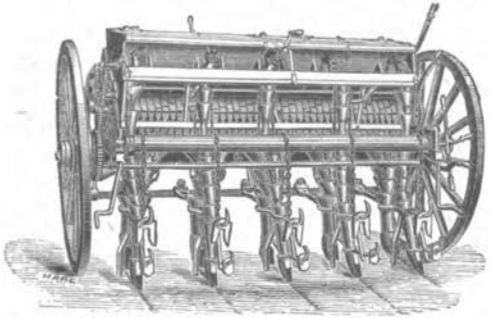


Fig. 74.

to act as a broadcast manure distributor, is illustrated in Fig. 74.

These drills are specially adapted for vegetable crops of every description. They can be fitted with any number of levers required, and the axletrees can be made to slip so as to alter the width to suit the different methods of cultivation, whether the lands be laid flat or on ridges.

The jointed iron lever is a valuable addition, as the manure and seed coulters, being fixed on levers acting independently of each other, and being pressed into the land by different sets of weights, may be adjusted with great precision, so as to deposit the manure and seeds at different respective depths as may be found most desirable. The quantity may be varied at pleasure from 1 to 150 bushels of any artificial or well-pulverized manures.

With the addition of another barrel, these drills may be used for drilling peas and beans at 12 inches, or any wider distance apart.

If required for drilling rough farmyard manure, a barrel with prongs is recommended in place of Chambers' artificial manure barrel.

Garrett's Improved One-horse Turnip and Manure Drill is shown in Fig. 75. This is a cheap and efficient drill for the purpose of drilling in rows on either flat or ridge-ploughed lands, turnip and mangel-wurzel seeds with rape, cake, guano, superphosphate, or any light pulverized manures. It comprises in a simple form most of the important features in the more expensive drills; the manure and seed coulters are connected by means of jointed iron levers to a swing beam in connection with the hind steerage. The manure may be regulated as required from 1 to 12 bushels per acre. The drill is 4½ feet wide, is very light, convenient, and easy of management, and its draught is within the capacity of a horse or pony.

Fig. 75.

Chandler's Liquid Manure Drill.—This machine is on the same principle as the dry manure drill. It will drill liquid in any state of fluidity, and any quantity per acre; it will also distribute liquid manure broadcast for top-dressings. It is proved to be the most certain means of growing roots on dry soils and in dry seasons; and it is now adapted for sowing corn and other seeds with the same correctness as turnips, with liquid manures.

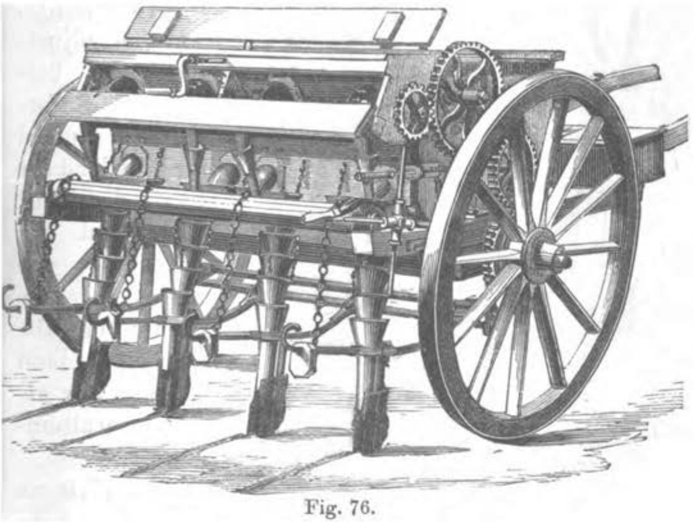


Fig. 76.

The drill is now manufactured by R. and J. Reeves and Son, Bratton, Westbury, Wilts, who have patented several improvements on it. One of these relates to the attachment of the cups or dippers. Formerly they were bolted on the cylinders, and were constantly getting loose and breaking off, causing loss of time and expense. They are now cast on the cylinder, and consequently there are no bolts to get loose, and a breakage is next to impossible.

Ridge Roller Turnip Drills.—A very excellent two-row drill of this class has long been in use in the North, where the turnip crop is a very important branch of husbandry. Like most other farm machines, these, too, have latterly undergone great improvements. The shaft adjustment and balance boxes formerly required for hilly land are now dispensed with, and the machines are made to sow evenly on the steepest land without any attention or alteration.

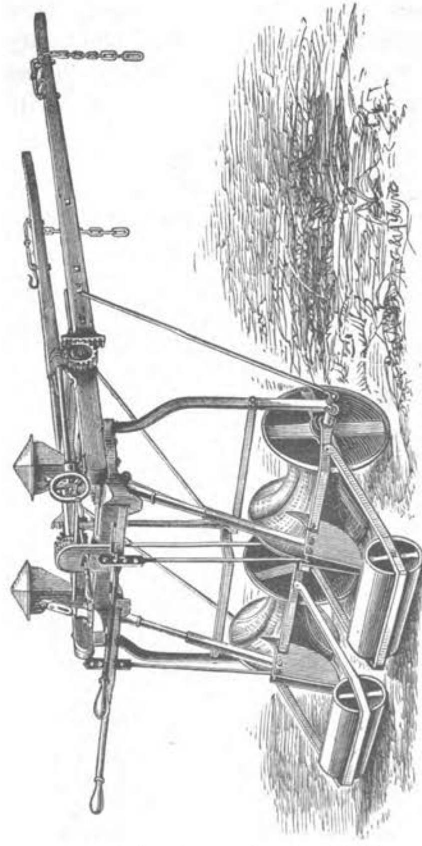


Fig. 77.

Fig. 77 is an engraving of the Prize Turnip Sowing Machine manufactured by G. W. Murray and Co., Banff. This machine has gained a high reputation in all parts of the country where ridge cultivation is adhered to. It exhibits all the modern improvements. The seed box is constructed on the disc-delivery principle, with the disc in the bottom of the box, so that equal delivery is obtained on hilly land as well as on the level. The back rollers can be detached when not wanted.

A very fine turnip sower of this class is manufactured by B. Reid and Co., Aberdeen. An illustration of this machine is given in Fig. 78. Like the machine previously described, it is constructed on the "Disc" principle, and is known as the Aberdeen "Disc" Delivery Turnip Sower. It embodies the best principles known, has been worked out with much care, so

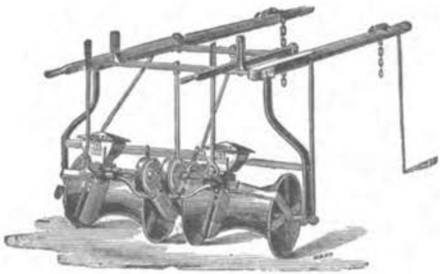


Fig. 78.

that it will distribute turnip seed under all circumstances, with the greatest regularity.

The advantages claimed for this machine are: firmness at work, combined with lightness; fixed spur gearing completely encased, which renders it impossible to miss; low seed boxes, so that no blanks can occur if a stop is made in the middle of the drill; disc in the bottom of the seed box, so that equal delivery is obtained in hilly land as well as on the level; can give any desired quantity of seed without change of gearing or stopping the machine; the rollers and boxes adjust themselves to any width of drill, so that the seed is always deposited in the centre of the drill; each roller and box act independently of the other, so that one can be used and the other not. The machine can be fitted with back rollers if required.

Both of the aforementioned ridge roller turnip sowers can be had adapted for sowing mangold as well as turnip seed.

A ridge roller turnip and mangold drill, Fig. 79, on the cup barrel principle, is manufactured by Holmes and Sons, Norwich. In this drill the weight is carried by the large wheels, and the cup-barrel is driven by gear-wheels. Each concave roller acts independently

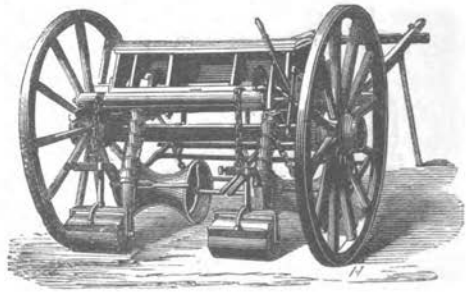


Fig. 79.

of the other, and can be adjusted to the different widths required, from 20 to 30 inches between the rows. It is fitted with flat rollers to cover the seed; and being fitted to the seed lever and made adjustable, the coulters can be set with a certainty of having the seed a uniform depth in the rows, however uneven the land may be.

The serviceableness of this machine would be vastly enhanced by the addition of a manure barrel.

Garrett's General Purpose Drill, for depositing all kinds of corn and seeds with or without manure, is shown in Fig. 80. It is fitted with Chambers' patent manure barrel and scraper.

The box in which the grain or seed is contained is made separate from the manure box, so that when the drill is required for corn or seeds without manure the whole manure apparatus can be removed.

The manure barrel is made upon Chambers' well-known principle for the delivery of either highly comminuted or rough manure, consisting of a cylinder formed of a series of rings, each having ribs or pro-

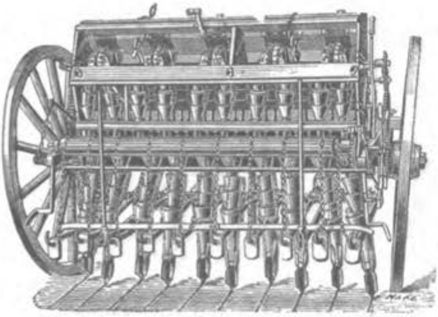


Fig. 80.

jections which come in contact with the scrapers placed beneath the box, the pressure of which is regulated to the greatest nicety by adjustable springs, according to the adhesiveness of the manure used. The manure box is fitted with a novel and excellent stirrer, which never fails to give a constant and regular delivery from the box to the barrel, however moist the contents of the box may be. It will sow from 1 bushel to any quantity required per acre, and is so easily adjusted by the slide that even when at work the quantity can be varied according to the quality of the soil, and without the change of gear-wheels.

When required, the drill can be provided with Chambers' patent broadcast trough, enabling the implement to be readily converted into a broadcast manure distributor. Patent double-jointed iron levers

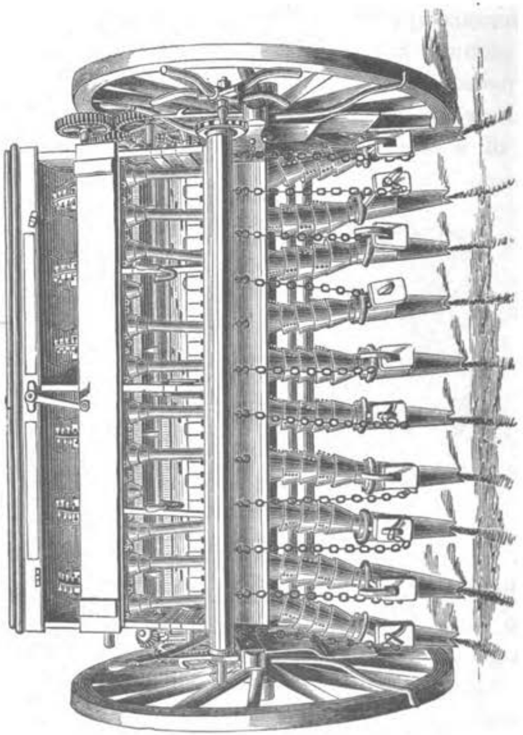


Fig. 81.

for depositing seeds and manure by separate coulters, but at the same time, can also be had when wanted.

Coultas' General Purpose Drill is shown in Fig. 81. These drills are adapted for all the requirements of the farm, being capable of drilling every description of corn and seed, with or without manure. The General Purpose Drill constitutes in itself:—

1. A complete corn drill.
2. A small seed drill.
3. A corn and manure drill.
4. A root and manure drill.
5. A perfect manure distributor.

They are made with two separate boxes, so that when required for drilling corn only, the manure apparatus can be easily taken away, leaving it as light and simple as if constructed for that purpose only.

A valuable addition is now added to the corn box to assure a uniform delivery of seed by the rack and pinion, to move the slides all equal and at once.

The manure box is fitted with Chambers' patent barrel and scrapers; the quantity of manure drilled being regulated by means of a slide acted upon by a lever, which gives the drillman ample power to raise and lower it when the box is full of manure and in work. A vibrating stirrer is fixed inside the manure box, by means of which a constant supply is kept to the barrel, however moist the manure may be.

The drills are fitted with double equalising lever-bars, which greatly decrease the draft, by which an equal pressure upon each coulter is obtained, as well as a more accurate delivery of seeds.

The table on the following page shows the number of rows, with their distances apart, which these drills are calculated to deposit, when the depositors are equally divided.

No. of Rows.	Spread of Carriage Wheels.	The width named to each Drill is the size generally made. If any alteration be required as to the distance between the Carriage Wheels or number of Rows, it should be mentioned when ordered.														
6	3ft. 6in.	Number of Rows . .	6	6	5	4	3	2								
		Distance apart in inches	6	7	8	10½	14	21								
7	4ft. 0in.	Number of Rows . .	7	7	5	5	4	3	2							
		Distance apart in inches	6	7	8	9½	12	16	24							
8	4ft. 6in.	Number of Rows . .	8	8	7	6	5	4	3	2						
		Distance apart in inches	6	6¾	7¾	9	11	13½	18	27						
9	5ft. 0in.	Number of Rows . .	9	9	8	7	6	5	4	3	2					
		Distance apart in inches	6	6½	7½	8½	10	12	15	20	30					
10	5ft. 6in.	Number of Rows . .	10	10	9	8	7	6	5	4	3					
		Distance apart in inches	6	6½	7¼	8¼	9½	11	13	19½	22					
11	6ft. 0in.	Number of Rows . .	11	11½	10	9	8	7	6	5	4	3				
		Distance apart in inches	6	6	7	8	9	10¼	12	14½	18	24				
12	6ft. 6in.	Number of Rows . .	12	12	11	10	9	8	7	6	5	4	3			
		Distance apart in inches	6	6½	7	7½	8½	9¾	11	13	15½	19½	26			
13	7ft. 0in.	Number of Rows . .	13	13	12	11	10	9	8	7	6	5	4	3		
		Distance apart in inches	6	6½	7	7¾	8½	9¼	10½	12	14	17	21	28		
14	7ft. 6in.	Number of Rows . .	14	14	13	12	11	10	9	8	7	6	5	4		
		Distance apart in inches	6	6½	7	7½	8½	9	10	11¼	13	15	18	22½		
15	8ft. 0in.	Number of Rows . .	15	15	14	13	12	11	10	9	8	7	6	5	4	3
		Distance apart in inches	6	6½	7	7½	8	8¾	9½	10¾	12	14	16	19	24	32

The General Purpose Drills of R. Hornsby & Co., Limited (Fig. 82), are fitted in three ways, as follows :

(1) with simple coulters to deposit corn and seed down the same conductors as the manure; (2) with every alternate lever double-actioned to deposit turnip and other seed apart from the manure; (3) with all the levers double-actioned to deposit corn as well as turnip or other seed, apart from the manure.

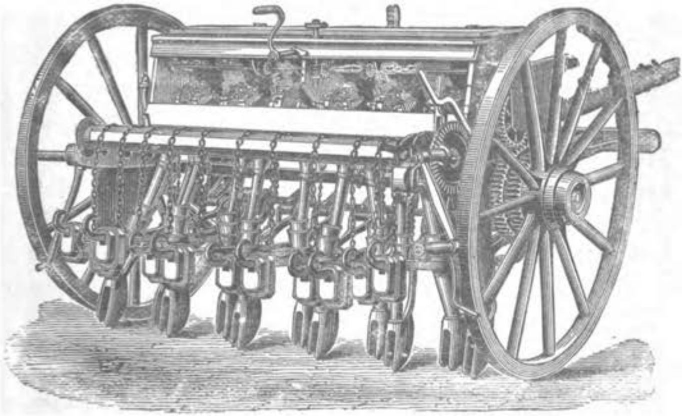


Fig. 82.

These drills are fitted with patent vulcanised india-rubber tubes, which are the best seed conductors known for regular delivery; especially valuable for light seeds, as beans and peas. They have two coulter-bars, whereby all the coulters deposit seed at an equal depth, and all the levers act independently.

CHAPTER XII.

SEED PLANTERS AND DIBBLERS.

Reeves' Patent Corn Sower for Ploughing in Corn.—Most agriculturists admit that under certain circumstances they would like to plough in seed corn, viz., on very light land, thus giving the plant a firm seed-bed; and also, in late wheat sowing, to be able every

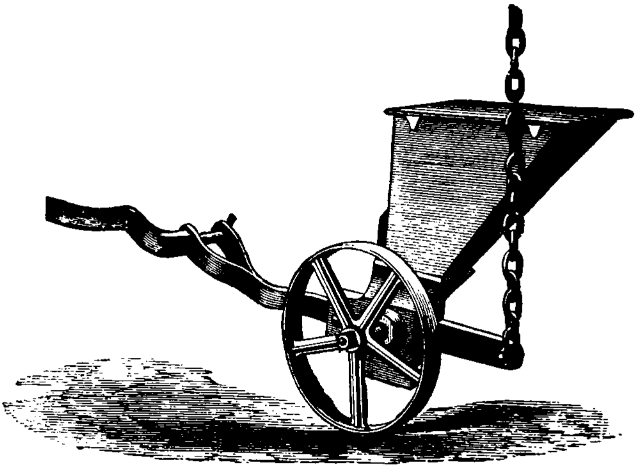


Fig. 83.

day to sow without extra labour all the land that is ploughed, in unfavourable weather for getting on the land. After it is ploughed the seed would be sown, and may be harrowed as soon as the weather admits. Corn put in in this way can be hoed as easily as drilled corn, and by using this invention hand-sowing is dispensed with.

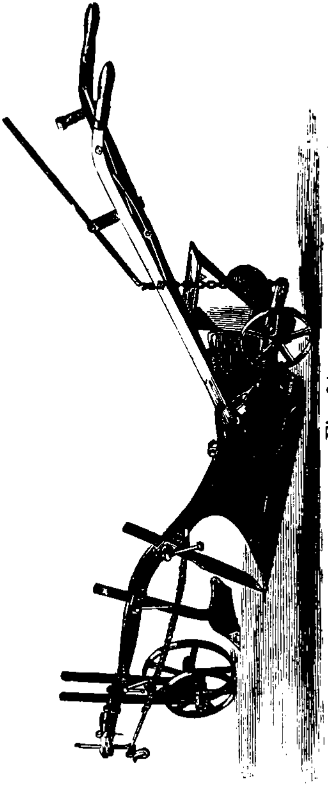


Fig. 84.

Reeves' Patent Corn Sowing Apparatus, for attaching to a plough, is shown in Fig. 83. Every kind of corn can be sown with this apparatus; and for sowing peas and beans, even when manure is ploughed in, it can be used, provided the time of ploughing in the manure is suitable for sowing. The beans, if required, can be dropped in bunches, so that they may be hoed. The apparatus is simply hooked on to an ordinary plough, as in Fig. 84, and can be taken off when required. It is equally suitable for attaching to a double furrow or a multiple furrow plough. When sowing peas or beans with a one-furrow plough, the corn sower is usually worked in alternate furrows.

The quantity of corn sown is regulated by a brush on the roller, which should be set so as to touch the roller lightly. If set down hard on roller it will sow a much less quantity, or if set a little off the roller it will sow much more. Different rollers are also used for sowing different kinds and quantities of seeds.

Howard's Multiple Plough with Maize Drill.—Fig. 85 shows a maize-drill attached to one of Howard's multiple ploughs. By this means the cost of sowing is avoided, and no seed is wasted by being exposed to birds or vermin. The seed is moreover sown at a uniform width and depth, and thus a more regular

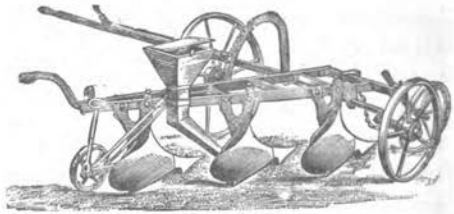


Fig. 85.

Fig. 86.

growth of the crop is insured. The drill is designed for planting maize, and is much used in the colonies, America, and other countries for this purpose, but it can be arranged for planting beans, peas, or other seed. The distance at which the seeds are dropped is regulated by the number of notches in the delivery roller, the rollers being easily exchanged; and the seed-box is put in and out of work by a lever handle to which a driving wheel is connected.

Seed Dibbler.—Fig. 86 represents Boby's* New Improved Dibbler. The grain is placed in the handle, and by pulling the spring at the side a motion is imparted to the slide which allows the grain to fall into the ground. The adjusting of the slide is

* Bury St. Edmunds.

done by the nut at the side according to the quantity and size of the grain to be sown. The price of the instrument is only 8s. 6d.

Potato Planters.—There are as yet only two kinds of potato planters, those constructed on the cup principle and those on the needle principle.

It may seem almost inconceivable that a machine can be made that will lay down or drop the potato sets in the bottom of the drill with the regularity of handwork. This, however, is easily accomplished with several of the machines now in use, and the saving of labour effected by such a machine is not to be despised.

The machines on the cup principle lift the "sets" from a hopper by cups which revolve on a drum while the machine is in progress. On the needle principle the potatoes are picked up in the hopper by a number of steel needles which are fixed on a revolving disc. The former are the more successful, and the ones generally adopted, in this country at least.

Murray's Patent Potato Planter.—This machine was originally brought out by Mr. Ferguson of Kinnochtry, who patented it in 1875; but it has since been much improved by Messrs. G. W. Murray & Co., Banff, who are the sole manufacturers of it. The machine consists of two large iron hoppers containing the "sets," and mounted on two travelling wheels, from whose axis an endless chain, formed of a series of cups, passes up through each hopper, each cup taking up a "set" as it goes. The sets are tipped over into a spout as the chain turns over its upper pulley, and are carried down with the chain to the bottom of the spout, whence they are discharged into the furrows.

This machine has hitherto been made for planting one and two rows, when the drills or ridges have been previously formed, the wheels running on the top of

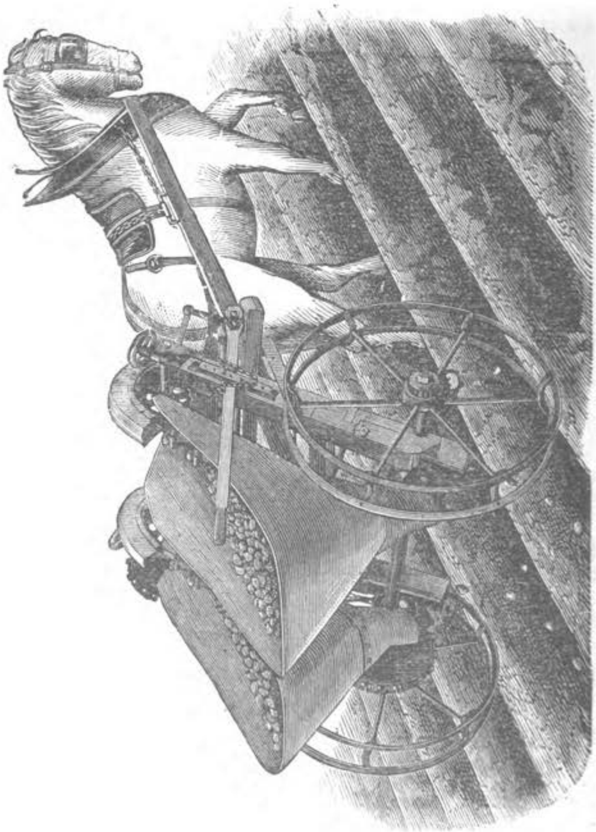


Fig. 87.

the drills, quite clear of the dung, and dropping the seed in the furrows.

A three-row machine is now made, having the wheels running in the bottom of the furrows, of a **V** form with a conical edge, and forming a nice groove for the potatoes to fall into. This machine is recommended when the land is manured in autumn.

As improved and protected by recent patents, the machine can be set to plant any desired distance between the rows, and the bottom of the spout is so arranged that no earth can be lifted by the cups.

The two-row machine on the improved principle appears to be the one which answers best. In using it, the land should first be set up in ridges or drills by the ordinary ridging plough; then when the machine goes along it cuts open the centre of the drill, plants the potatoes, and covers them up. The coulters and coverers working upon the top of the ridge break up any clods, and leave two or three inches of the finest mould covering the newly planted sets.

The planter, which is drawn by two horses, requires besides the driver another person in attendance, and can easily get through 6 acres in 10 hours.

The price of the two-row machine, for opening the ridges, planting, and covering the seed, is £20.

Coultas' New Potato Planter (Wright's Patent).—This very ingenious implement, which was brought out by Mr. Lewis Wright in 1871, and is manufactured by Mr. James Coultas, is constructed for planting potatoes in rows. It opens the ridges, drops the potatoes at equal distances, distributes any quantity of artificial manure, and covers them up at one operation, without in any way damaging the sets.

The seed potatoes, whether whole or cut, are placed in a box, from which they are taken one by one by endless chains, havings links of such a shape as to form a series of cups. These chains deliver the potatoes to the tubes which deposit them, while other tubes are provided for manuring. From the tube the potato falls into the furrow that has been opened by the ridging plough fixed on the lower part of the frame. The small hopper at the top of the machine is furnished with one of Chambers' manure barrels, and delivers the artificial manure down the wooden shoots into the two open furrows over the potatoes; the furrows are then closed by the action of the four covering breasts, and the land left flat. The small wheels at the side of the covering breast regulate the depth of the furrows. The long handle to the right is used for raising the ploughs and breasts when turning on the headlands. The price of this machine, complete, is £45.

CHAPTER XIII.

BROADCAST SEED DISTRIBUTORS.

Grass and Clover Seed Distributor for Hand Labour.—These machines are most convenient, and are very generally used for sowing grass and clover seeds amongst young barley or other corn. A man will sow

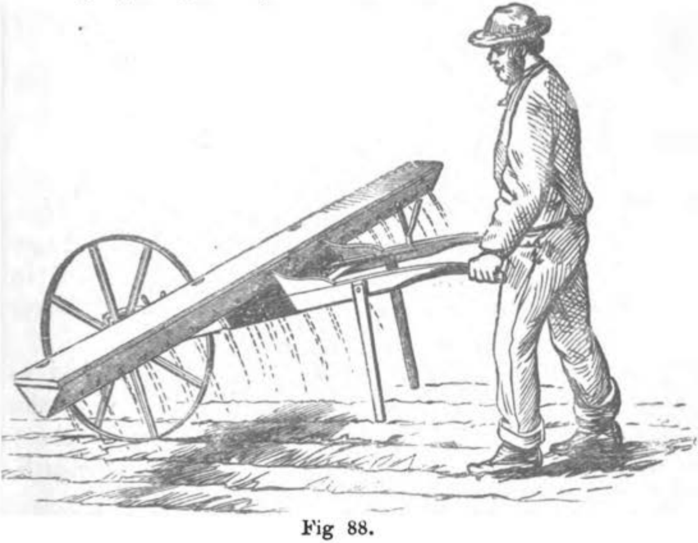


Fig 88.

twice as much ground in a day, with half the walking, as he can do in broadcasting these small seeds by hand, and the seeds are more evenly distributed.

Fig. 88 is an illustration of a complete and efficient machine of this kind, manufactured by the Bristol Waggon Works Company. Its construction is simple, the brush spindle extending the whole length of the box, and deriving its motion from the travelling wheel; and the quantity distributed can be easily regulated by altering the perforated copper discs through which the seed is brushed. It is fitted with a continuous slide or regulator, and is put in and out of work by means of a small lever or striking gear, which avoids the trouble of lifting the seed-box. When not in use the box is carried diagonally on the barrow. The usual length of box is 12 feet.

Larger broadcast machines, adapted for sowing corn and all kinds of seeds, are also constructed on the "brush" principle, but not so much as formerly, the "cup" and "disc" machines, presently to be noticed, having in a measure displaced them.

Broadcast Corn and Seed Sowing Machines (Kæmmerer's Patent).—This machine, Fig. 89, is manufactured by James Smyth & Sons, Peasenhall, and will sow all kinds of corn or seeds. It is an article much in demand for the colonies, America, Russia, and other foreign countries.

The corn or seed is delivered by cups (attached to revolving discs) into tubes, which conduct it to the triangular blocks of the distributing board; by these it is divided, and finally falls upon the pegs beneath, and a perfect distribution is the result.

The quantity per acre can be regulated at pleasure, each machine being furnished with an ample number of cog-wheels for that purpose.

The distribution being so regular, far surpassing that done by manual labour, it is not necessary to use so much seed per acre.

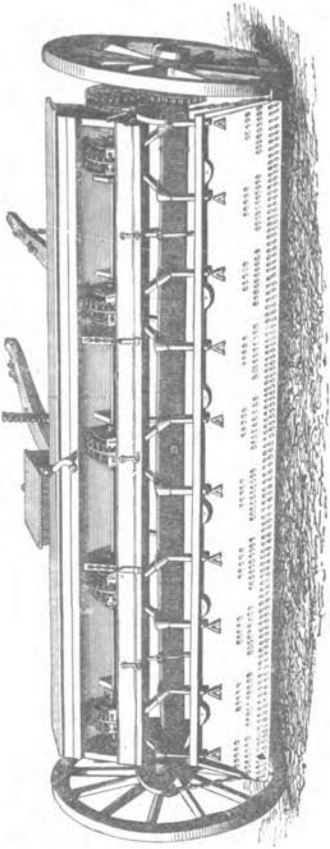


Fig. 89.

With a 10-feet machine 25 acres can be sown per day, or with a 12-feet machine 30 acres.

"Disc" Broadcast Sowing Machine.—The Patent "Disc" Broadcast Sowing Machine, by B. Reid & Co.,

Aberdeen, is illustrated in Fig. 90. It will sow all kinds of grain and seed.

In this implement the axle only revolves as the machine advances, so that no seed drops out in turning up the headlands. The seed-box is also near the

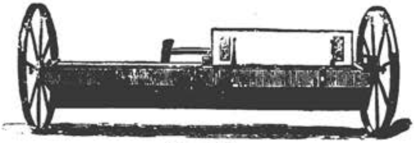


Fig. 90.

ground, so that the machine can be used in windy weather. When working up or down hill, the seed is sown at the same pace without any adjustment.

It is fitted with Sams' patent "disc" seed discharge,

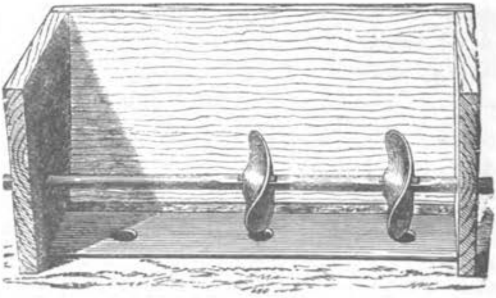


Fig. 91.

shown in Fig. 91, which is a very simple and efficient substitute for the cups and brushes commonly used in drills and seed distributors. The "disc" is waved, so that in each revolution four deliveries of seed are made into the holes beneath it, the size of these holes being regulated by a sliding bar, with similar holes adjusted beneath the seed-box by means of a handle in the middle of the machine.

CHAPTER XIV.

BROADCAST MANURE DISTRIBUTORS.

A VARIETY of machines have been constructed for the purpose of distributing manure, both liquid and in a solid state.

For crops that are drilled, the best plan is to deposit the manure, wet or dry, with the seed, as described in the chapter on drills; but as all crops are not drilled, and it is of importance to sow some manure broadcast, various implements or machines are in use for that purpose.

Carts for distributing liquid manure have been described and illustrated in another volume of this series,* and need not be more than mentioned here.

Garret's Broadcast Manure Distributor.—In this machine, Fig. 92, the manure barrel is made upon Chambers' well-known principle for the delivery of either highly comminuted or rough manure, consisting of a cylinder formed of a series of rings, each having ribs or projections which come in contact with the scrapers placed beneath the box, the pressure of which is regulated to the greatest nicety by adjustable springs according to the adhesiveness of the manure used. It is also fitted with a novel and excellent stirrer, which never fails to give a constant and regular delivery from

* "Irrigation and Water Supply," chaps. v. and ix.

the box to the barrel, however moist the contents of the box may be. It will sow from one bushel to any quantity required per acre, and is so easily adjusted by the slide that even when at work the quantity can be varied according to the quality of the soil, and without the change of gear-wheels.

Messrs. R. Garrett & Sons have recently succeeded

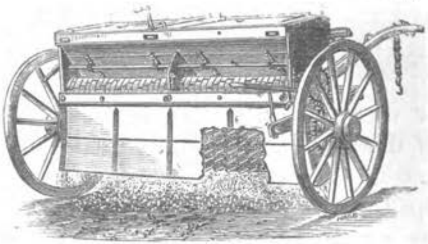


Fig. 92.

in attaching to the above well-known implement a small box for turnip and mangold seeds and five iron levers, by means of which the vegetable crop may be drilled in rows at the usual distances apart, at the same time with the chemical or artificial manures. The result of this combination is an exceedingly light and cheap seed and manure drill. When the implement is not required for work as a drill, the seed-box and levers are very readily detached, and, with the ordinary trough and screen supplied for the purpose, the broadcast manure distributor is ready for use in its original form.

Hornsby's Broadcast Manure Distributor.—This new patent manure, salt, sand, soot, &c., distributor, Fig. 93, has a rotary barrel, with projections arranged spirally throughout its whole length. These projections have each a scraper to remove from them the substance being distributed as they carry it from the box or hopper; but each scraper works independently, so that if any one presses too lightly on the barrel it can be set closer without necessitating an alteration of the

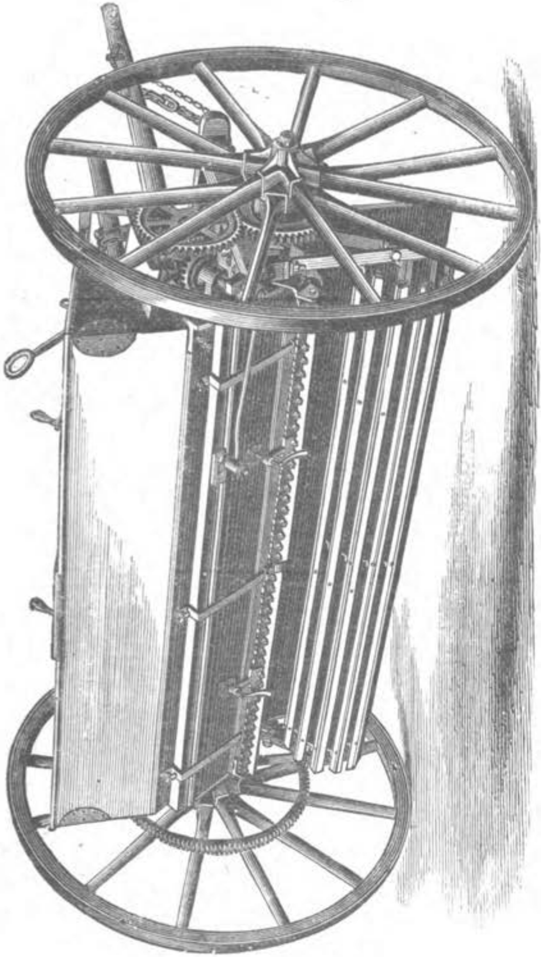


Fig. 93.

adjustment of the remainder. The barrel is fixed on the main axle, and therefore revolves in the same direction as the travel of the road-wheels, and is driven by a spring-clutch to throw it in or out of gear.

The rotation of the barrel being in this direction, the man can be in front, a seat being provided for him to ride on, in such a position that he can see and thoroughly control the action of the machine, instead of having to walk behind as formerly.

In the hopper is a set of stirrers moving at a slow speed to and fro upon a plate, and keeping the substance from sticking. These stirrers are driven from the main axle, and the plate and stirrers can be instantly removed for cleaning. The substance, in falling from the barrel, drops upon a rotary distributor, which spreads it evenly and equally upon the whole surface of the land. The slow speed of the barrel and stirrers, and the openness of the box, prevent the manure being so much worked up into a paste as is commonly the case.

B. Reid & Co.'s Manure Distributor.—This new patent

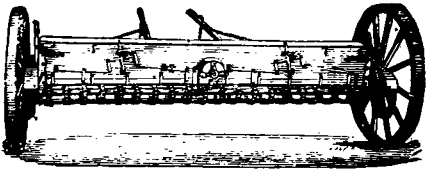


Fig. 94.

machine will distribute crushed bones, dissolved bones, nitrate of soda, superphosphate, guano, soot, lime, or any artificial manure in good condition. As will be seen by referring to Fig. 94, the machine is drawn by one horse, and consists of a hopper, which can be made any size that may be desired, and can be arranged to distribute broadcast or in drills.

When the horse moves, motion is communicated from the wheel to a shaft at the back of the machine. On this shaft are a number of cog-wheels at equidistant places. On these cog-wheels are placed endless chains, which come through the bottom of the box, carrying the manure with them. The manure immediately falls, the chain passes over the cog-wheels, the cogs clearing every link of it, so that it goes round and enters the box clean again, and a continuous stream of manure is always flowing.

The quantity per acre is regulated by a slide placed above the holes, which opens or closes so as to allow a larger or smaller quantity to pass. A greater variety of quantity can be had by driving the chains faster or slower. This is done by a set of change-wheels, which are supplied with the machine.

Farmyard Manure Spreaders.—Various inventions have been tried for this purpose, but, in this country at least, none of them seem to have been much of a success as yet. In America, however, the Kemp manure spreaders, and other implements of a similar class, seem to have succeeded well, and are extensively used.

The manure spreader consists of an apparatus which can be attached to the tail of an ordinary cart or waggon. It distributes the manure more evenly, finely, and perfectly than any hand-spreading can do, and in much less time and at much less expense. The work once done by the machine nothing further is needed, whether applied as a top-dressing for mowing land or for ploughing under. The advantage of spreading the manure at once is also very great, as all waste of the fertilising constituents is thereby avoided. The economy of such an implement, therefore, cannot be doubted, when it is an efficient one, by any one who wants to do such labour at the least expense, and to make the most of the manure.

CHAPTER XV.

HORSE HOES, TURNIP THINNERS, AND POTATO DIGGERS.

The horse hoe possesses many advantages over hand-hoeing, the chief of which are the greater rapidity of the operation, a more thorough stirring of the surface soil, and the consequent economy of labour.

Corn or root crops of every kind, drilled in rows of not less than 7 inches apart, may be hoed in a perfect manner at a cost of about 1s. an acre. Hand-hoeing of corn crops especially costs seldom less than 4s. and frequently 6s. or 7s. an acre.

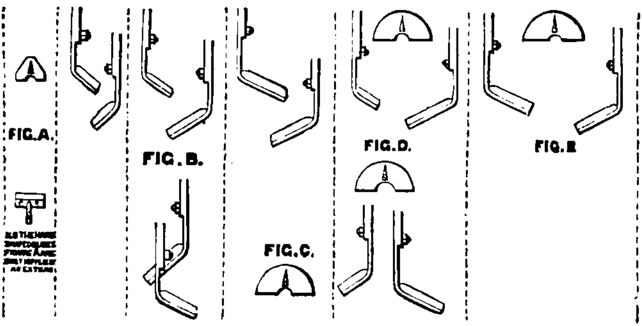
Fig. 95.

Garrett's Improved Lever Horse Hoe.—In this implement, Fig. 95, the frame-work is so arranged that the fore steerage of Garrett's drill can be utilised for the horse hoe when required, whilst for stetch-work the horses can be worked on either quarter by means of shafts bolted to the frame.

The lever by which the levers are raised is well within the reach of the steersman, who can hold the lifting lever in one hand and the steering lever in the other.

The depth of every hoe-blade can be separately regulated by means of stalks secured by wedges and set screws, and the " pitch " of the whole of the blades and the level of the lever-bar can be adjusted to the greatest nicety by means of a simple lever arrangement on either side of the frame.

The most approved arrangements of the hoe-blades



For Wheat,	For Beans and Peas,	For Turnips or Mangel-Wurzel,
at less than 8in. use one 5in. A or hand-shaped Hoe.	at 10 to 11 in. use one each 4 and 7-inch Hoes.	at 14 to 19 in. use one each 4 and 7-in. and one semi-circular Hoe.
at 8 to 10 in. use two 4in. L Hoes.	at 12 to 13 in. use two 7-in. Hoes.	at 20 to 30 in. use two or more 7-in. and one semi-circular Hoe.

Fig. 96.

to suit the conditions of various crops and systems of cultivation are illustrated in Fig. 96. When the plants are large, the arrangements B, C, and D are recommended.

Coleman and Morton's Steerage Horse Hoe.—This horse hoe is shown in Fig. 97. The steel shares are fitted with a socket and fixed on the stem, in the same manner-as on Coleman's well-known cultivator, so that any size may be fixed on the same stem. It has a very simple and effective arrangement for regulating the pitch of the hoes; also for altering the line of draught so that any tendency to draw out of the right line is prevented, and the work of the man using it made as easy as possible.

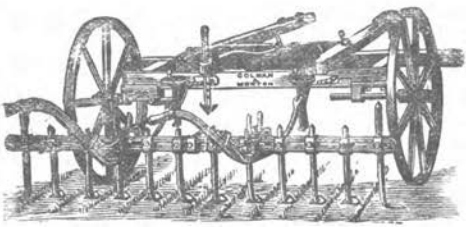


Fig. 97.

The handles can be raised or lowered to suit the convenience of the man working it, and at the land's-end the frame of hoes can be raised in an instant for turning.

It is adapted for hoeing wheat, beans, peas, &c., and can be steered to the greatest nicety, so as to avoid injury to the plants. The two side hoes can be adjusted to suit the furrows. The hoes are well-secured to the frame, and can be set wider or narrower at pleasure. It is equally suitable for hoeing on the stetch or flat.

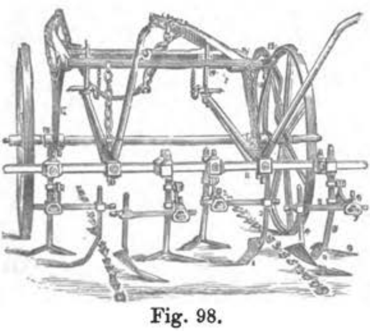


Fig. 98.

Goss and Savage's Horse Hoe. — This horse hoe attracted a good deal of attention at York in 1883, where it was awarded a medal by the Royal Agricultural Society.

These hoes are specially adapted for hoeing young plants as soon as they appear above the ground, without covering or injuring them in any way.

The principle of the hoe is peculiar, and the method adopted to get near the plants without covering them is to run the hoe with the point out of the ground so that it gradually cuts in without throwing the soil out at the side. It is very simple but thoroughly effective, and in the case of land invested with live mustard or other annual weeds, or in fact with any weeds in a season like this when turnips braird badly, it will be simply invaluable. It does two drills at once, and its price is £13 10s. It can be easily adapted for flat or raised drills, and is equally effective on either.

Single Drill Hoes or Grubbers.—Vipan and Headley's Improved One-row Horse Hoe is illustrated in Fig. 99 It is entirely made of wrought iron, with steeled tines, and is intended for cleaning turnips or potatoes between the drills, and will be found a most useful and efficient implement. It will be found an invaluable implement for loosening and dressing the land in an orchard, or between the rows of vines.

These hoes combine lightness with strength; the beam and handles are in one piece. The back hoe stems are fixed under the double part of the beam in a grooved block, and held by loop and nut on the top side of beam, making them adjustable both ways. All the stems are fitted with cast-steel hoes and blades, which are made uniform, so that when the blades are worn new ones may be easily replaced.

These steel blades will cut off the weeds better and go through foul land more easily, without burying the plants.

Corbett's Horse Hoe or Turnip Scuffle.—This implement is illustrated in Fig. 100. In its construction the wrought-iron cutters with upright arms are entirely

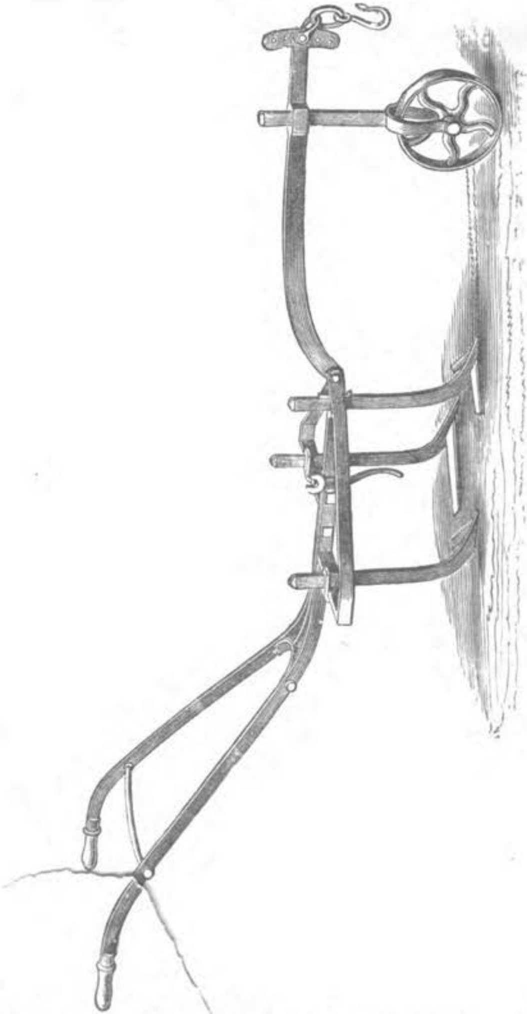


Fig. 99.

dispensed with, a cast-iron skim turned up at the sides being substituted, by which means the probability of blocking or choking is impossible. This skim is cast in two parts, which renders it movable to suit any width of ridge. The edge or cutting surface of it is serrated instead of being plain, thereby causing it to lay firm hold and cut off any thistle or strong weed it may fall in contact with, and being chilled it is far more economical for use than the ordinary tines. By the introduction of a simple arrangement, the pitch of the frame can be immediately altered when the point becomes worn without moving the wheel, which causes the scuffle to run quite steady; and the inconvenience of having the handles pitched up to make the implement work is not needed. But the most important feature in this hoe is the use of a revolving harrow, which entirely forks out all the weeds and rubbish, and leaves them on the surface quite loose and exposed. The draught of the implement is also very considerably reduced by its use, and the work is far more cleanly done, as the rubbish is not gathered and deposited in heaps, as is the case with the old style of harrow.

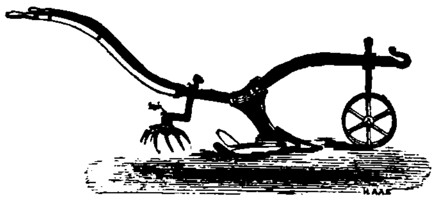


Fig. 100.

Turnip Thinners.—These are merely another form of horse hoe which have appeared within the last ten or twelve years under the name of turnip thinners or bunchers. They are intended to set out the young turnip plants in bunches at regular intervals, and are adapted to work both on flat ground and on the ridge. As no machine of this kind can "single" out the plants, or do more than bunch them, its usefulness is thereby diminished; but still, where there is a large acreage of turnip crop, all alike ready for the hoe at one and the same time, and hand singlers are scarce, an implement of this kind if employed to block out the plants ahead of the hand hoers is a considerable economiser of labour at a season when it is often much needed.

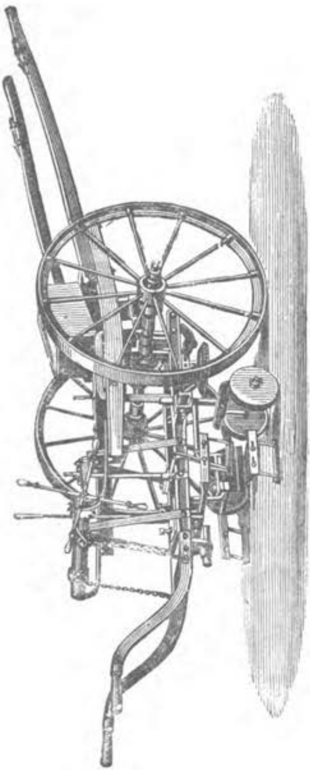


Fig. 101.

Fig. 101 is an illustration of Holmes & Sons' (Norwich) Turnip Thinner, an implement which has been awarded prizes by various agricultural societies. The construction of the implement and its mode of working will be fully understood from the engraving.

Potato Diggers.—In these machines the potatoes are generally unearthed by a deep cutting blade or broadshare, which raises the plant, while a rapidly revolving wheel with projecting arms scathes the tops, by which means the tubers are thrown out of the ground ready to be gathered.

A tuber is now and again bruised or cut, but the percentage of injured tubers is so small, in the case of the most improved machines, that there is now very little complaint on this head.

Of course no such implement can work well on wet ground; and in wet seasons it is well to have the potato tops pulled before the machine goes to work.

Hanson's Potato Digger.—This machine, Fig. 102, is manufactured by Coleman and Morton, Chelmsford. It will take up potatoes cleaner than they can be taken up in any other way, and without injury to the crops. The economy in using this implement is so great that its cost is saved in one season in taking up 20 acres of potato crop. The digger is so constructed that the same implement will work either on light or heavy land, and at whatever width the rows of potatoes are planted, from 20 inches upwards.

Fig. 102.

The use of the machine does very much less damage to the potatoes than is the case with the fork. Lifting potatoes with the fork costs at least £3 per acre; whereas a pair of horses in the machine will dig four acres a day, and the hand gathering is then reduced to about 10s. or 12s. per acre

Jack's Potato Digger.—A novelty in this machine is that the stem of the broadshare is in the rear of the delivery, and is therefore not liable to be choked with tops.

When the share is set to the proper depth for passing under the potatoes, it loosens and raises them as the revolving fork throws them out.

Another distinctive feature of this machine is, that it works up and down successive rows like the turn-wrest or one-way plough. By simply shifting the starting lever, the revolving fork is made to deliver the potatoes for the pickers, to the right or left as may be desired.

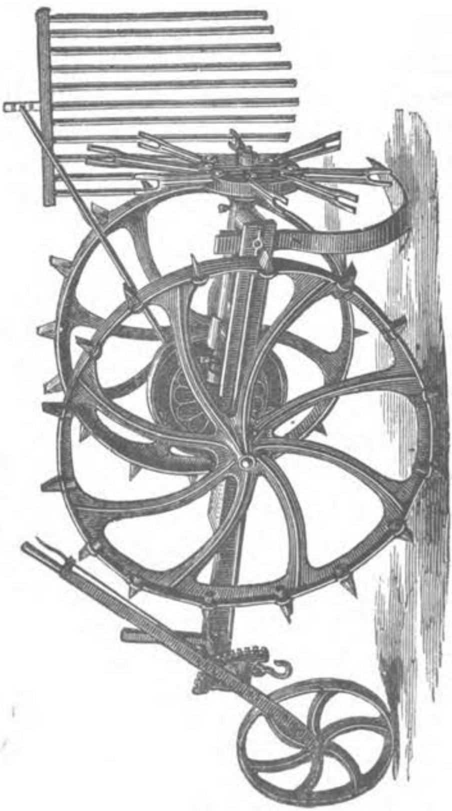


Fig. 103.

The large driving wheels, which are adjustable upon the axle to suit the width of ridges, have permanent projections upon the rims, which give the necessary grip for driving the revolving forks without the addition of spike or stud pieces. The fore carriage is provided with a lever for lifting the front wheels when turning; the machine then becomes balanced on the large wheels, and is thus very easy to turn, as well as to remove from place to place.

CHAPTER XVI.

STEAM CULTIVATION.

THE advantages resulting from the employment of steam-power in tillage operations are now generally recognised. One chief advantage is that it renders the farmer comparatively independent of labour; at all times he has an enormous power at his command on a moment's notice, and is thus able to deal with the land when in a fit state for cultivation. Another great advantage is that when the ordinary operations of breaking-up are done at the proper season it will be found that no mechanical pulverization is required. The rapid motion of a steam-driven implement tears and breaks up the land so that it remains in a loose, rough state, and the atmosphere, acting upon the subsoil as well as on the upper part of the staple, permanently raises the temperature, pulverizes the whole by degrees, and thoroughly prepares it for the reception of the seed. All injurious treading by animals is avoided, and the roots of plants can readily penetrate to the subsoil.

In estimating the expense of steam cultivation few justly appreciate the great change that it effects in the character of the soil, both as regards its drainage and the cost of after tillage. When land has been once thoroughly broken up by steam every succeeding operation requires less power; and the experience of those who have used steam proves that one-half only of the usual operations is required.

The value of steam tillage has been well exemplified from another point of view in droughty autumns. In very dry seasons, such as 1865, 1868, and 1870, after all harvest operations were concluded the stubbles were so hard and dry that many farmers were compelled to wait for rain before they could be ploughed by horses, whereas those who had the steam plough got to work at once, and had large breadths of land broken up and cleaned in the most efficient manner, the result of this thorough cleaning and tillage being most apparent in future crops.

There are now ploughing engines capable of exerting 100 indicated horse-power, and capable of putting a draught of 3 or 4 tons upon an implement at a rate varying between three and four miles an hour. With such power any reasonable depth can be reached, and as the disintegrating power is, by a well-established mechanical law, as the square of the velocity, the soil is broken up with four times the mechanical effect at four miles at hour, as in the case of a horse-drawn plough at two miles an hour.

In the words of the carefully considered report of the committee of the Royal Agricultural Society on steam cultivation (1867): "A culture deeper than it is possible for horses to effect works a highly beneficial change in the texture of the soil, imparts additional efficiency to drainage works, augments the value of the manure applied, brings into operation certain latent properties of the soil which much increases its fertility; and it also fits land formerly unfit for the growth of turnips, allows of their being fed off by sheep, the operations of the field are economised, and the growth of all crops is stimulated."

"These are," says *Engineering*, "the remarks of a committee who had been labouring industriously for months in examining the results of steam cultivation upon nearly two hundred steam-tilled farms in all parts of England and in some parts of Scotland, and are simply the deductions of the best experience. At the time of their report steam-tillage was not only better but was considerably cheaper than horse-tillage. Now, the steam-engine, rope and other tackle, and the attached implements have been very much improved, and the comparison would be still more in favour of steam. It would be something to save 2s. or 3s. per acre upon the 10 million acres of tillage land in England yearly, and experience shows that this saving of £1,000,000 to £1,500,000 can certainly be accomplished. But the greatest gain is in the improved crops due to thorough tillage, and this may amount to an extra quarter of wheat, an extra 3 or 4 tons of turnips, or something equivalent, and in this way the average crop may be increased possibly to the extent of £10,000,000. There are many recorded instances of steam-ploughed fields yielding 2 or more quarters of wheat per acre more than they did under horse-tillage."

No doubt the cause of steam-tillage has suffered from an indiscriminate use of deep ploughing in certain instances; but that has been a misapplication of the power.

On the other hand, in addition to ploughing and cultivating, great benefit is found to follow the application of steam-power to the drilling and harrowing in of seeds on heavy soils, especially in wet seasons, as the iujurious effects of trampling by horses is thereby avoided.

Systems of Steam Cultivation.—Of the many schemes and systems of steam cultivation which have been practically brought before the public two only (and those the simplest) have proved thoroughly successful. In both of these the traction-power is transmitted to the implement through a steel wire rope winding upon a drum. In the one plan the two winding drums are fixed in a windlass frame, and connected to a stationary steam-engine, which can be worked from one corner of a field. One end of each rope being made fast to the plough, the implement is drawn backwards and forwards by the drum pulling alternately, and the pulley, sheaves, and anchors at each end of the furrow move forward as the implement proceeds. In the other system each of the winding drums is placed under the boiler of a self-moving steam-engine, and one engine at each end of the furrow alternately pulls the plough towards it, while the other moves forward into position ready for its return. These two systems are known as the single engine or roundabout, and the double engine or direct method of steam cultivation.

In noticing these two methods of working we shall take the double engine system first. It must be understood, however, that any method of steam cultivation must needs involve considerable modification in detail to work equally advantageously under all circumstances. Under most other machinery a steam-cultivating apparatus is required to work under greatly varying conditions, and often under circumstances where nothing whatever has been done to assist its introduction. The general formation, the condition and requirements of the country, the nature of the soil, the size and arrange-

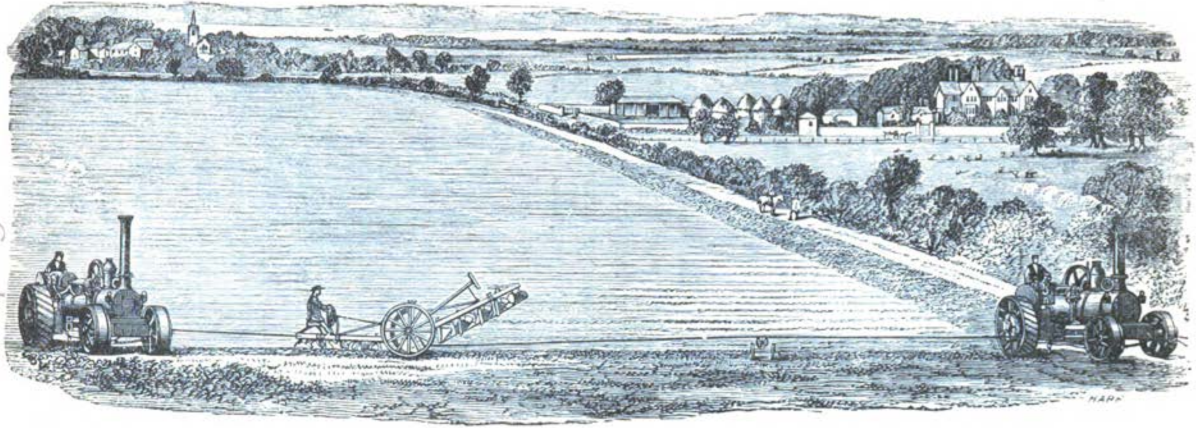


Fig. 104.

ment of the holdings, and the available capital, are all items which influence the application of steam-ploughing machinery, and may demand important modifications in its construction.

The Double Engine System.—Fowler's direct method of working is illustrated in Fig. 104. It includes two self-moving engines with winding drums, 800 yards of steel rope, and the necessary implements. The engines are worked on opposite headlands, and each alternately draws the implement towards itself, the engine not in work paying out the rope while moving forward into position for the return journey. Any kind of implement may be used.

The advantages of the double engine system are—the short length of rope required and consequent economy of power, the facility with which the machine is set to work and taken up, and the small amount of wear and tear, due to the simplicity of the tackle. Its disadvantages are its first cost, and the difficulty of moving the engines on very soft or wet land. The last difficulty has been, however, almost entirely removed by increasing the diameter and width of the driving wheels.

For large farms and for letting for hire this system is the best, and has proved itself capable of doing more work per day at less cost than any other. Land can be ploughed by it at one-half the cost of horse-power.

Fig. 105 shows an engraving of Fowler's Single Cylinder Steam Ploughing Engine. These engines are made of 6, 10, 14, and 20 horse-power. They are constructed with single steam-jacketed cylinders, and are provided with steam domes. The road-gear is constructed of spur-wheels, and made entirely of the best crucible steel. The road-wheels are wrought iron, from 16 to 24 inches wide. The engine has two

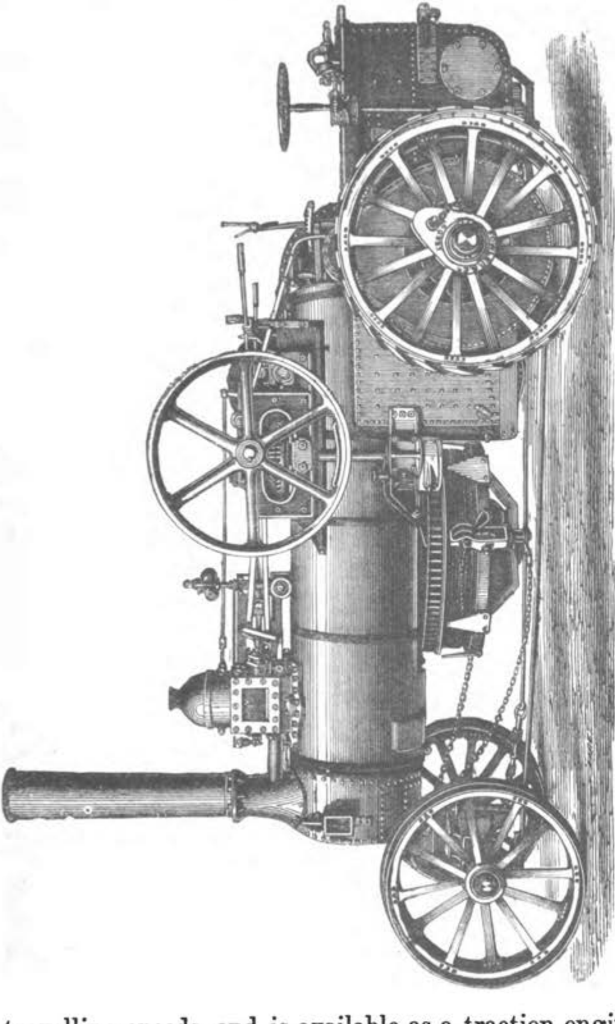


Fig. 105.

travelling speeds, and is available as a traction engine, and can be used for any agricultural purpose, such as threshing, pumping, grinding, sawing, or any operation of the kind.

The power is conveyed to the winding-drum by an upright shaft from the crank-shaft. The winding apparatus consists of a horizontal drum, which, by means of coiling gear, winds and unwinds the wire rope uniformly without any attention from the man in charge. This is done by a self-acting lever, which carries two vertical guide pulleys, moving slowly up and down, and freely swinging round the drum into any position at which the rope has to work. By this means all strain on the rope, as well as on the apparatus, is avoided.

The Improved Single Engine System.—Howard's steam ploughing machinery on the single engine system is shown at work in Fig. 106. This is an improvement on the old single engine or roundabout system, as the engine here employed (Howard's "Farmer's Engine," for ploughing on the single engine system) is not stationary, but moves itself along one headland. The automatic anchor, which is remarkably simple and effective, moves along the opposite headland at each bout as the work proceeds. In this way much less time and labour are required to start work in the field than with any other single engine system, and a shorter length of rope is used. Only two men, the engine-driver and the ploughman, with a lad for the rope porters, are employed.

The advantages of the single engine system are in the comparative cheapness of the tackle, and in its superior fitness for very hilly or awkwardly shaped fields, as it can then be worked on the stationary or roundabout method with two automatic anchors. Its disadvantages consist in loss of power, great length of

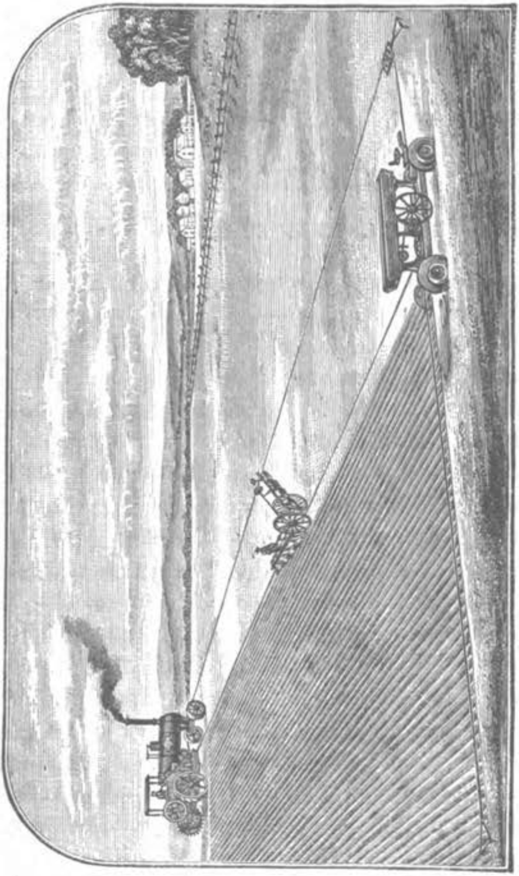


Fig. 106.

wire rope, wasteful expenditure of time in removals, and great quantity of apparatus necessary.

CHAPTER XVII.

IMPLEMENTS USED IN STEAM CULTIVATION.

THE implements used in steam cultivation are all made on one of three principles:—

1. Balance implements.
2. Turning implements.
3. Implements which go backward and forward without either turning or lifting.

Balance Plough.—Fig. 107 represents Fowler's Patent Balance Plough, made for two to eight furrows, as circumstances may require, the construction of which has been considerably improved by the patented invention of a simple plan of always obtaining an adjustable width of furrow. The rigid iron frame, which is so essentially necessary to all steam-driven implements, is still maintained, and the alteration of the width of the furrows is effected by means of a wedge, which throws the ploughs at different angles to the frame. This wedge does away entirely with bolts and screws, and renders the position of the ploughs thoroughly rigid, at the same time is the best means of altering the width of the furrows. Several operations can be performed by this implement without much alteration.

The frame is so arranged that the shape of the ploughs and mould-boards can be varied to suit any circumstances that the land may require. Any class of mould-board can be supplied. By removing the ordinary mould-board used for surface ploughing and substituting short ones or "digging breasts," a tillage can be effected quite equal if not superior to spade husbandry, which leaves the land in the most desirable state for the action of the atmosphere. From the shares and mould-boards being attached on the outside of the beam all choking in very foul land is obviated.

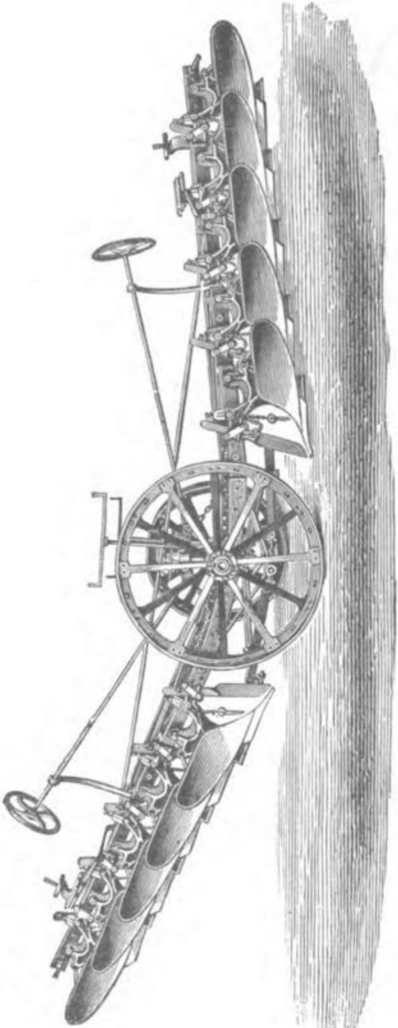


Fig. 107.

In ploughing lea and other land for cereal crops, from the speed of the plough the work done is sometimes rough and rather too loose, unless a land-presser or consolidator is attached to and drawn behind the plough. It is necessary to have the presser one furrow larger than the plough; by the use of the presser a firm seed-bed is secured.

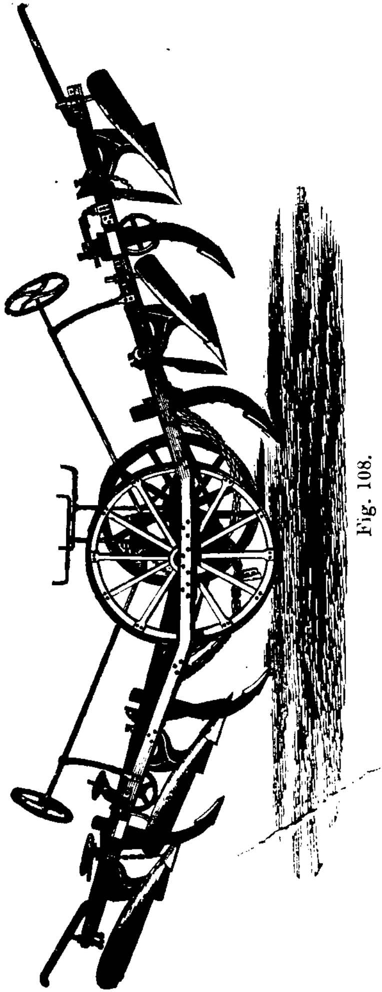


Fig. 108.

Subsoil Plough.—This implement (Fig. 108) is constructed by J. Fowler and Co., and worked on the principle of a balance plough. Besides the ordinary ploughs attached to it, it is fitted with tines, one tine following each plough and breaking up the subsoil to any required depth without throwing it on the top of the land. In some land it is simply ruinous to bring the subsoil at once to the surface. But by admitting the atmosphere it may be gradually prepared for this operation.

Sutherland Reclamation Plough. — This (Fig. 109) is also an implement invented by Fowler and Co., and has been much used by them in carrying out the Sutherland Reclamation works. It is so constructed that the most stony land can be cultivated without trouble or breakage. It will be seen from the engraving that it is preceded by steel discs, which lift the plough over the stones or obstructions, so as not to break the mould-board. The plough will turn a furrow 2 feet wide by 15 inches deep completely over, and it will be observed that the turning of the furrow-slice is not altogether effected by the mould-board, but is very materially assisted by the rollers, which catch it at the moment of leaving the plough. The stones which have been passed over are caught by the hook-tine, which comes behind the plough, and torn out. They are then removed by men. The tine thoroughly subsoils the land to a depth of 2 feet, and materially assists the drainage of the soil. This implement has been largely used for the last three years in the reclamation of land in Sutherland.

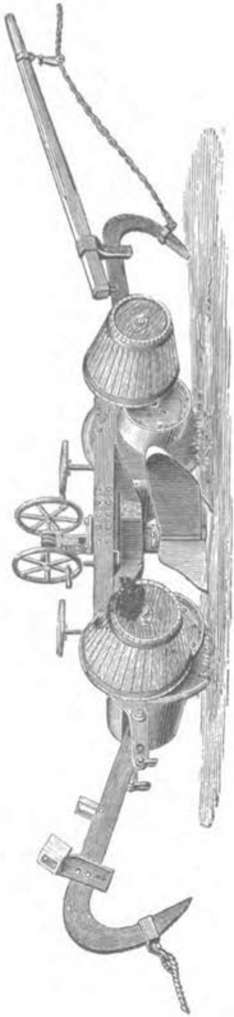


Fig. 109.

Turning Cultivator. — Fowler's Patent Turning Cultivator (Fig. 110) is adapted by all systems of steam-cultivating machinery. It consists of a strong iron frame, carrying, according to circumstances, from 5 to 13 tines, and resting on three road - wheels, the front wheel being flanged and used for steering. The axle of the two hind wheels is cranked, so that by turning it the frame is lowered or raised, and the depth of the tines adjusted. The long end of a draft bar or "patent turning lever" is provided with two arms, to which the two ends of the ropes are attached. The arms are set at an angle to keep the tail rope clear of the implement. The lever itself is held by a vertical stud fixed to the

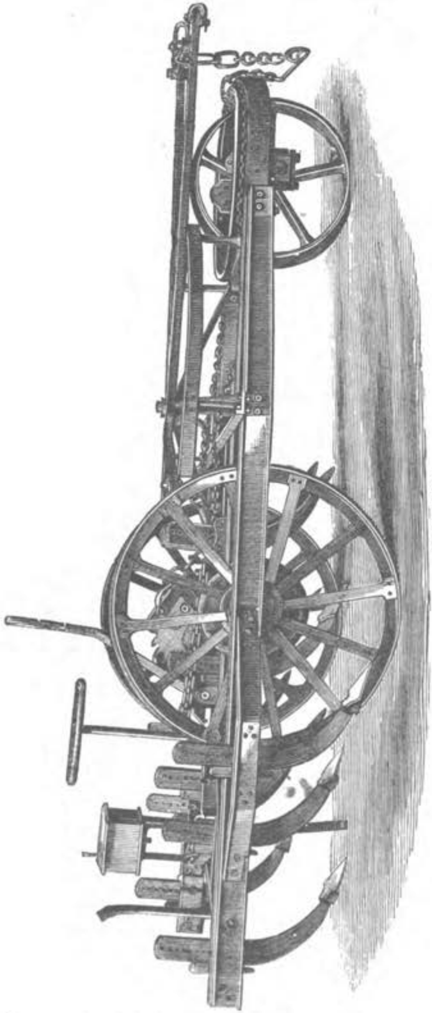


Fig. 110.

frame considerably behind the steering wheel. This position of the draft stud (the subject of a special patent) gives the necessary liberty and power to the steering wheel, and enables it to lead the implement at almost any angle out of the line of the pulling rope. On the short end of the turning lever is a chain communicating with a quadrant on the crank axle, and as the lever is pulled round the chain acting on the quadrant turns the axle, lifts the frame, and raises the tines out of the ground. The plan of operation is as follows: as soon as the cultivator is brought up to the headland the reverse pull brings the lever round and lifts the tines out of the ground, and they are held up by a catch; when lifted the required height the lever strikes against a stop, and the implement turns into new ground; the man (who never leaves his seat) releases the catch, the tines drop into the ground, and the implement is drawn across the field.

The principal advantages of this implement are as follows. Its size is only limited by the power of the engines, which thus may be used to their utmost capability. It smashes up the soil, working steadily, and always preserving a perfectly uniform depth. Even the largest implements of this description require only one man in attendance. In rounding round no additional work is required, and scarcely any time is lost, whilst the implement, however wide, at once moves into new land, leaving small and regular headlands. On average soil 30 to 50 acres per day may be efficiently cultivated. Ridging bodies attached to the frame of the cultivator make an effective and easily handled ridging implement. The ridging bodies are attached without taking away the tines, and both operations are done at the same time.

This implement is well suited for the last operation in autumn, as it effectually exposes the soil to the action of the atmosphere.

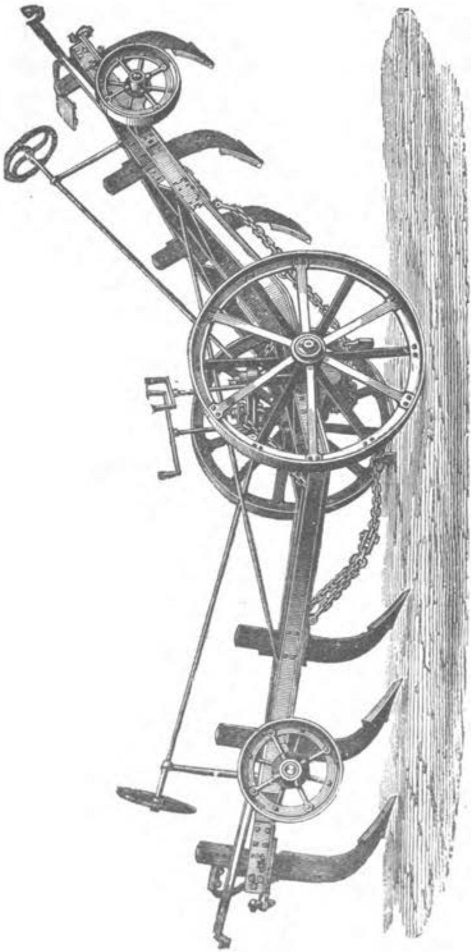


Fig. 111.

Grubber or Knifer.—This instrument, Fig. 111, is also one of Fowler's, and is extremely valuable on stiff clay land. By working it two feet deep, the subsoil can be stirred and aërated without at all interfering with the surface. The benefits which result from this operation are of the utmost importance. By its use the land is quite altered in its nature, and the advantage to the crops has been of very marked description. The drainage is also greatly assisted, and we wish to call the special attention of occupiers of clay land to this implement. It is made with one, two, or three tines.

It is also adapted for removing tree-roots or stones, and can be worked 3 feet deep.

This is an excellent implement for stirring up the subsoil of old grass land, and to all owners of clay land it is a decided advantage.

Turning Harrow.—Fowler's Patent Turning Harrow for steam cultivation is shown in Fig. 112. The difficulty occasioned by the ordinary cultivator turning up more callous stuff than is desirable in the spring of the year is entirely obviated by the use of this implement, which, it will be seen, is a combination of

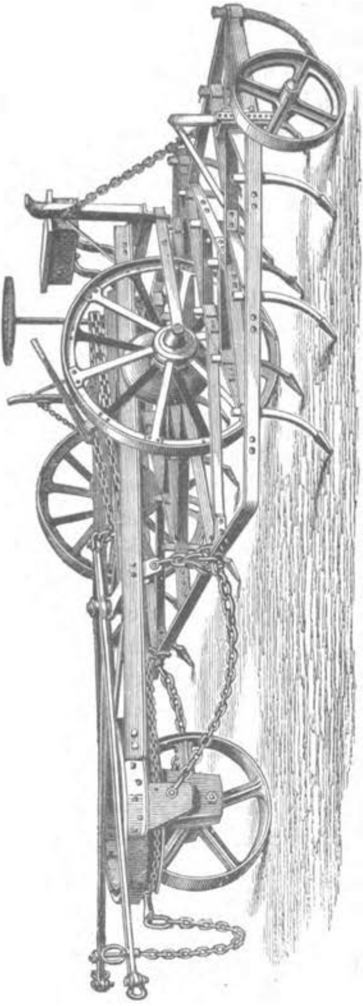


Fig. 112.

cultivator and harrow, and is adapted for doing work which may be described as half-way between that effected by a cultivator and harrow, and superior to any horse cultivation.

Two kinds of shares are made for this implement—one a board share for cutting the whole ground, the other a square-pointed share for moving the soil only; but the requirements of the farmer will always determine which of these should be used. As a matter of economy, it is advisable to keep a complete set of tines and points of each kind always in stock.

This implement is constructed in three pieces so as to accommodate itself to uneven surfaces, and will take a breadth of 10 to 15 feet; it is especially designed to work in land that has been steam-ploughed, dug, or cultivated in the previous autumn, and it will do everything necessary in the spring to insure the land being in a proper state for any kind of crop. The steering frame is so arranged that it will take different harrows, from the lightest seed-harrow up to regular light cultivating tools; it also can be fitted with light ridging ploughs. In a similar way to the action of the cultivator previously described, it is lifted at the end and turned round, thus getting into new work at once.

Three ridging bodies can be put on the steering frame by removing the harrow frame.

This exceedingly useful implement is made of wrought iron, with welded sockets for the tine.

A light harrow or any such implement can be hung behind it if desired.

Howard's Steam Harrows.—These harrows are very suitable for pulverizing and cleaning land after it has been broken up by the steam cultivator. With "The Farmer's Engine," or the roundabout system, 15 to

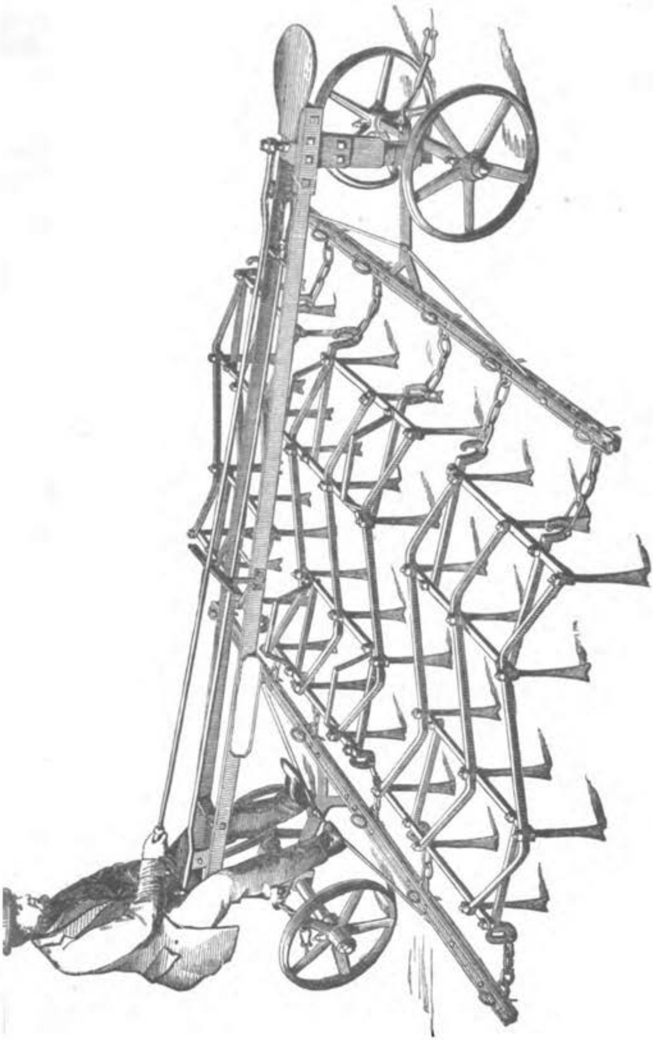


Fig. 113.

20 acres may be harrowed in a day. The tines of the

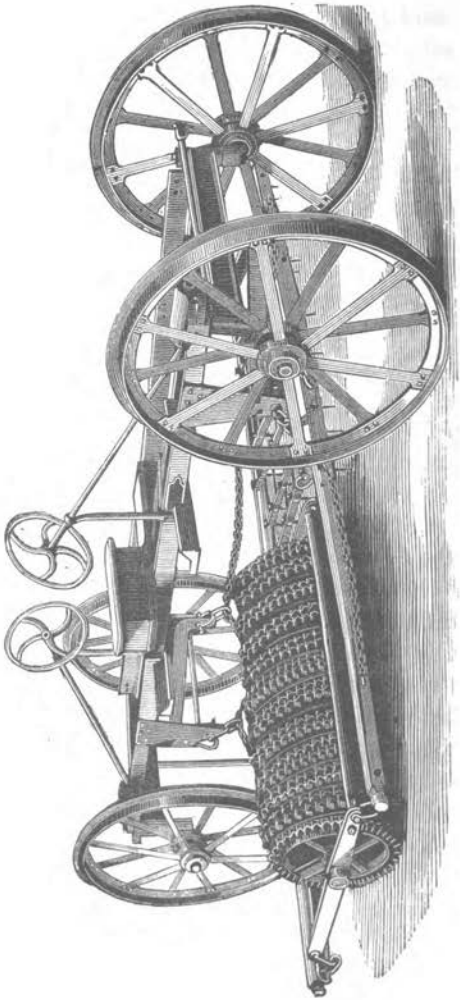


Fig. 115.

day are efficiently drilled and harrowed without the trampling of the seed-bed by horses' feet.

CHAPTER XVIII.

MOWING MACHINES.

A MOWING machine consists of three main parts:—

1. The *cutting apparatus*, which travels close to the ground, generally carried on a wheel at each end.

2. A *frame containing the gearing* which puts the cutting apparatus in motion.

3. The two *main wheels*, which support the frame, and furnish the motive power to the gearing.

The pole or shaft, by which the horses are attached to the machine, is generally fixed to the axle of the travelling wheels.

The transmission of the motion to the cutting apparatus is effected generally in one of two ways:—

First, one or both of the main wheels have an internal ring of teeth, into which gears one or a pair of pinions, which are carried on a first-motion shaft, and transmit their motion to it by means of ratchet-boxes and pawls. They thus convey motion to the cutting apparatus only when the machine is moving forward, the wheels revolving independently when the machine is being turned or moved backwards. On the first-motion shaft runs loose a bevel-wheel, which gears into a bevel-pinion keyed on a longitudinal-inclined shaft. On the front end of this shaft is fixed a crank-disc, and a connecting rod is used to couple this crank with the horizontal reciprocating knife. Clutch-gear is generally used fo throwing the bevel-wheel in and out of gear with th shaft.

In the *second* method of obtaining the requisite motio for the knife, the travelling wheels transmit their for ward motion to the main axle itself, through ratchet boxes and pawls, and thence to such a train of gearin as is necessary to obtain the proper speed for the knife This class of machine is used chiefly in cutting artificia grasses, which are not so difficult to deal with a natural meadow-grass: and also where the crops ar light. The chief advantage of this method of driving is that it enables the whole of the gearing to be com pletely boxed or covered in, and so protected from dirt; on the other hand, such machines are much heavier in draught, owing to the point of application o the power being so much nearer to the centre of the axle.

The *cutting apparatus* consists of a flat bar, to which are attached a set of pointed projections or fingers, having a horizontal slot or space cut across them, and in this slot the knife is caused to work back and forward. The knife is composed of a number of steel triangular sections or blades riveted upon an iron or steel bar or back. On each end of the finger or cutter-bar is fixed a shoe, supported by a small wheel, which can be adjusted so as to raise or lower the cutter-bar from the ground. The cutter-bar is attached to the main frame by a hinged connection, and is capable of being turned up and held in a vertical position, for the purpose of travelling more easily along roadways and passing through field-gates.

When the machine has been once round the field and starts again, a clear path or track is necessary for the horse which walks round nearest to the standing-crop and also for the travelling wheels; and this is

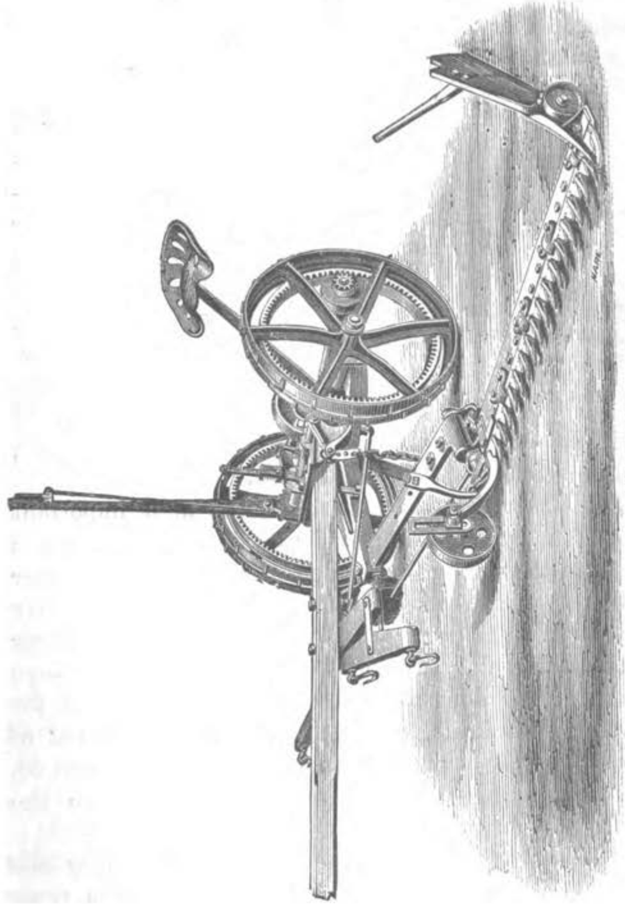


Fig. 116.

provided for by hinging to the off-side shoe, at the outer extremity of the cutter-bar, a trackboard inclined inwards towards the main wheels. To the tail of this board is fixed a round stick still more inclined inwards towards the wheels, so that, as the grass is cut and passes along the board, the stick turns it over and forms a swathe. The wheels and horses pass on each side of this swathe in making the following cut.

In Howard's Simplex Mower, Fig. 117, their patented principle of open gearing is adopted. This gearing, among other advantages, is light in weight, of great strength, and not liable, as other gearing, to get clogged with the cut grass, there being no cogs to catch it, and no shield therefore is required.

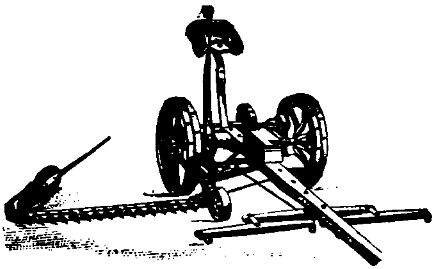


Fig. 117.

The cutter-bar forms, perhaps, the most important part of a grass-mower; in Howard's machine this is attached to an improved sledge, and in such a manner that the framework of the machine works perfectly well over ridges and out of furrows. A self-locking latch for keeping the connecting rod in the knife-eye also prevents clogging, and can be readily opened for changing the knife. By a lever close to the hand of the driver the centre-bar is under complete control. The connecting rod delivers a direct thrust to the knife.

How to harness Horses for Work in a Mowing and Reaping Machine.—The proper harnessing of a team for work in mowers and reapers is so important and yet so seldom carried out that we append here the following engraving (Fig. 118), and remarks on this point, which have been issued by Messrs. Samuelson & Co. in connection with their mowers. A team suitably harnessed and properly yoked will save valuable time

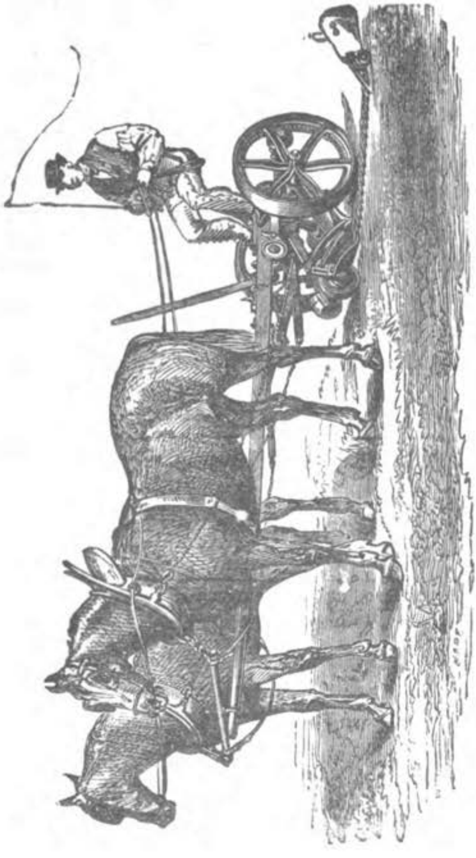


Fig. 118.

in the field, and enable both the driver, horses, and machine to do their work much better and more pleasantly.

The drawing shows a pair of horses properly harnessed to a mowing machine, and it will be observed :—

(1.) That a good set of double harness should be provided, but without breechings.

(2.) Each set of harness should be provided with a back-band, a small belly-band, and martingale.

(3.) A strong pair of pole-straps should also be procured.

Then, in harnessing, the belly-band should go from trace to trace, the martingale should be buckled round the cross-bar to pole, and go from thence to the belly-band, and the pole-strap should bring the cross-bar well up to the collars. When the team is thus harnessed the pole cannot rise in backing, and the machine will back easily; but if the pole is not thus prevented from rising by the martingale, backing becomes very awkward for both horse and driver. Breeching is quite useless for this purpose, because it cannot prevent the pole from rising, and its absence is a great comfort to horses in hot weather.

CHAPTER XIX.

REAPING MACHINES.

REAPING machines are divided by Mr. Samuelson into three classes.

(1.) *Back-delivery Reapers,* or those which deliver the cut crop at the back of the beam, as in a mower.

(2.) *Side-delivery Reapers,* or those which are provided with a platform, on which the cut crop falls, and is then raked off to the side of the machine by revolving rakes.

(3.) *Self-binding Reapers,* or those which cut the crop and bind it into sheaves.

Back-delivery Reapers.—A reaper of this class is a much more simple piece of mechanism to deal with than a mower, because there are not the same difficulties to contend with in the case of dry crops or corn as of green crops or grasses. The *speeds are consequently slower,* the *working parts fewer,* and the *strains not so severe.*

The simplest of all reapers is the *Manual Back-delivery,* in which a man has a seat provided for him on the body of the machine, in front of the driver's seat, and using a short hand-rake collects the standing corn into the knife, where it is cut, and falls upon a platform which is hinged to the cutter-bar. This platform is held in an inclined position till sufficient corn is cut and collected to form a sheaf, when the man, by means of a foot-lever, allows the platform to drop backwards upon the ground; the sheaf is then deposited on the ground. As soon as the sheaf is raked off, the platform is raised again to its inclined position, and a fresh sheaf is collected.

This form of platform may be attached to the cutter-bar of an ordinary two-wheeled mowing machine, and an extra seat fixed upon the main frame for the raker, just above the inside main wheel; this with a special off-side shoe constitutes the arrangement of a

Combined Mower and Manual Reaper.

The off-side shoe of a reaping machine differs in size and construction from that employed for mowing, because of the height of the corn and the difficulty of separating it. It carries dividing irons (or prongs) **V**, which project some inches into the crops, in advance of the cutter, and thrust on one side the standing corn so as to admit of a clear passage for the shoe and wheel.

In the *Self-delivery Back Reaper*, the place of the raker is taken by a revolving reel, which is driven by suitable chain gearing from the axle of the machine. This reel has usually three blades which collect the corn on the platform, and one rake which rakes the sheaf off.

The reaper pure and simple—that is a machine intended as a reaper only—is carried on one broad main wheel at the near side, and supported by a small wheel fixed to the off-side shoe. The frame and gearing are carried by the main axle, and the beam or cutter-bar is bolted on to part of the main frame. The cutting parts, or fingers and knives, do not differ materially from those of the mower, with this slight exception that in some cases where the crops are very dry, and on some parts of the Continent and in America, the edges of the sections or blades are serrated, thereby causing a sawing action rather than a cutting one. The first motion is usually taken from a ring of teeth cast on, or attached to, the inside periphery of the travelling wheel; but in some cases from a spur wheel fixed on the main axle, as in the second class of mowers.

In both the *manual-delivery* and *self-delivery back delivery* reapers, it is necessary to tie up and remove the sheaves before being able to go round the field a second time; and this objection led to the *side-delivery machine.*

Side-delivery Reapers.—In this class a (quadrantal) platform is fixed on the back part of the cutter-bar, and is suitably supported off the ground by stays. On the main body of the machine is an upright shaft, to which are fastened four or more rakes. These are caused to revolve, and in so doing gather the standing corn to the knife, and then rake it backwards off the platform when cut, throwing it to one side behind the main travelling wheel, and thus leaving a clear track for the horses on the following round.

This is where the cut corn is left in *swathe.* Where it is desired to leave it in *sheaf,* it is necessary to substitute for some of the *rakes* what are termed "gatherers," which only gather the standing crop to the knife, and then pass clear over the cut grain lying on the platform, which thus accumulates there until the next rake comes round and sweeps the sheaf off.

Howard's Simplex Reaper, which comes under this class, is illustrated in Fig. 119. A feature in this machine is the arrangement of *controllable rakes*, any of which act as dummies or rakes at the will of the driver; they are worked by a simple treadle, so that the sheaf can be kept upon the platform at the corners, thus leaving a clear space to turn, and avoiding all treading of the corn by the horses. The tilting lever works so easily that the finger points can be instantly lowered when coming to parts where the crop is laid and for passing over obstacles; the same lever will incline the points upwards.

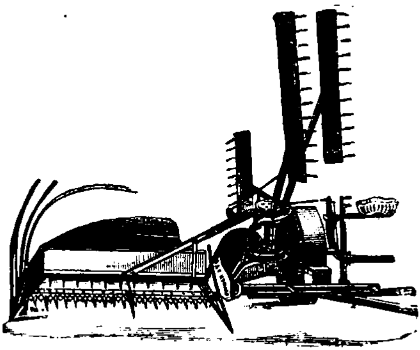


Fig. 119.

To the cutter-bar a set of laid corn-lifters can be readily attacked; these effectually raise up storm-broken or laid straw, and thus avoid the ears being cut off or passed over by the machine.

Hornsby's "Indispensable" Combined Mower and Self Raker.—In the construction of this machine a combination of excellences has been attained which only long experience and the most painstaking experiments could render possible, the leading points which have distinguished the maker's various mowers and reapers having been embodied in it. Combined mowers and reapers have long been known, but such a combination as this is altogether novel. The most important feature in the machine is the arrangement of a mower with cutting apparatus in advance of the main wheel axle, and a reaper with cutting apparatus behind the main wheel axle. It is well known that a mower with cutting apparatus behind will not follow the undulations of the ground, and the driver is not so securely fixed as when the cutting apparatus is in advance. On the

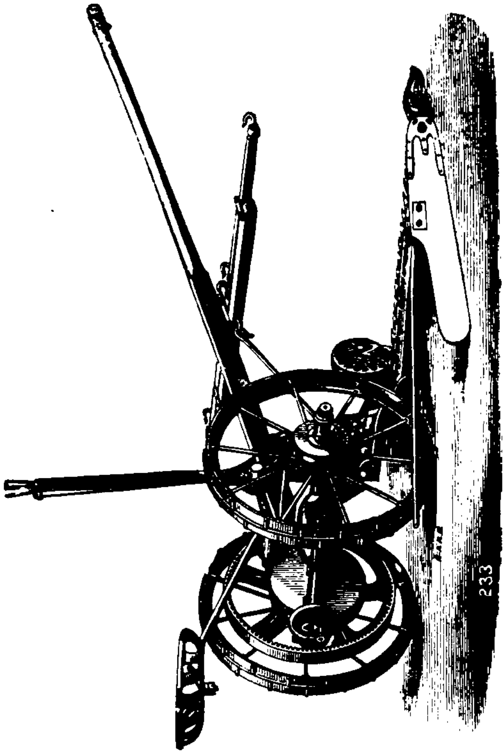


Fig. 120.

other hand, a reaper with the fingers in front would, when working over ridge and furrow land, or cutting up a hill-side, rake up the soil, and the knives and fingers be damaged by stones, &c., and in cutting down the hill they would be elevated so as to cut higher than is desired.

As a reaper it has the speed of knife most suitable for cutting grain crops or artificial grass, and an increased speed when used as a mower (Fig. 120) to cut meadow grass.

Self-binding Reapers.—A machine of this class at once cuts the corn and binds it into sheaves. For a long time these reapers had one common fault—the binding medium was wire, and in spite of every care particles of metals would find their way into threshing machines and into other situations where their presence was not desirable; but our agricultural engineers have now produced machines which do equally efficient work, and bind the sheaves with harmless string. These machines cut and bind at the rate of one acre per hour, with no other assistance than one man and a pair of horses. They save a shilling or two per acre in the cost of harvesting; but their chief advantages lie in the power they give the farmer to expedite reaping operations and in the better work done. Manilla string is the material usually employed for tying purposes, and the cost varies from 1s. and upwards per acre, according to the weight of the crop.

The self-binding reapers of different makers vary somewhat of course in details, but their general principle is this: First, the cut grain is carried by means of endless webs across the platform, and then over the drive wheel and down an incline until its passage is stopped by a bar standing vertically across its path. "Against this bar the grain is packed until a bundle big enough for a sheaf is formed. Then the bar, which is arranged to give way under a certain pressure, moves, and in doing so puts into gear the 'binder,' a curved arm which comes up from below, and after passing the binding string around the bundle leaves its end in the grasp of the 'knotter.' Finally this clever device first ties and then cuts the twine band, leaving the sheaf free to be kicked off the machine by a pair of levers provided for that purpose." (Pidgeon.)

The Self-binding Reaper is rapidly superseding every other form of reaping machine.

Hornsby's String Sheaf-binding Harvester.—This machine, which was awarded the £100 first prize of the Highland and Agricultural Society of Scotland, and the silver medal at the Northamptonshire Agricultural Society's Show, 1882, is shown at work in Fig. 121. It cuts a width of 5 feet 3 inches, and the draught of the machine is so light that two horses can readily work it.

The process of binding and delivery is automatic throughout. The crop as cut falls on a travelling platform, and is thence elevated over the main road wheel and on to the binding table, where it is received by packers of simple and effective construction, which thrust it forward, laying it in the cord and against the compressing lever. When sufficient bulk has been accumulated to form a sheaf of the proper size (the size having been previously determined, and the apparatus set accordingly), the compressing lever is moved by the force of the packers pressing the sheaf against it, bringing into action the binding arm, and subsequently the knotter and ejector. The binding arm (carrying the cord) rises from beneath the table, making a clear division between the sheaf to be bound and the succeeding crop, and, carrying the cord over the sheaf, lays it in the knotter, which is certain and unfailing in its action;

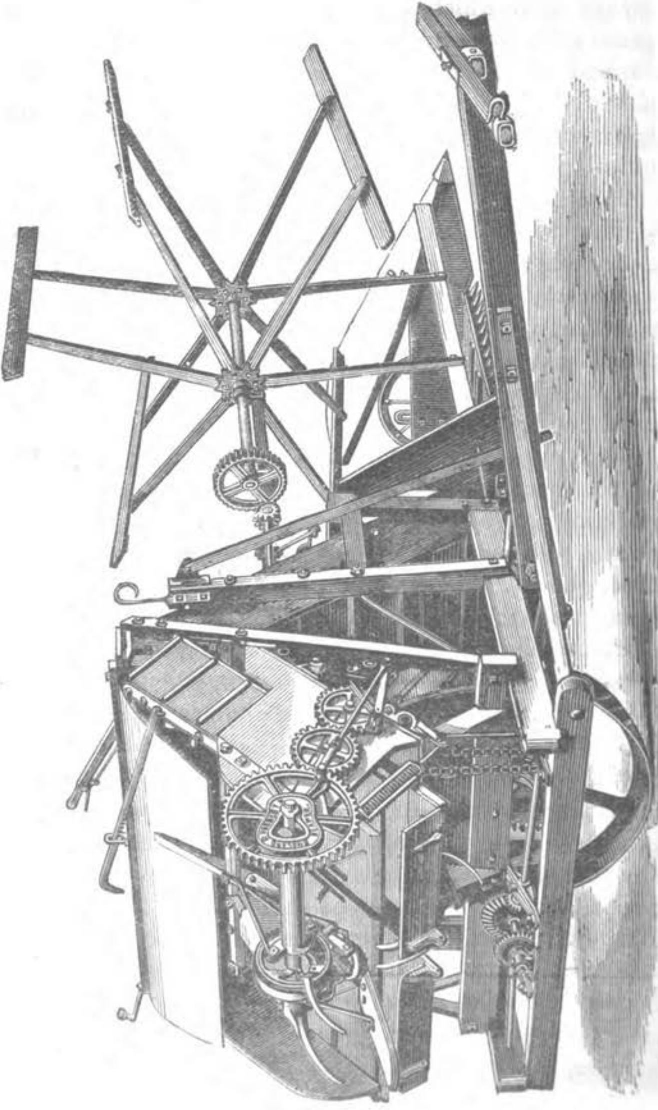


Fig. 121.

the knot is then tied, and the sheaf quietly ejected from the machine.

The binding material is either hemp or manilla string at the option of the user, no alteration of the machine being required in changing from one to the other. The former is recommended as being cheapest and best.

The entire machine is most conveniently arranged, the finger-bar can be raised or lowered as required, and the driver can, without leaving his seat, effect the following adjustments, viz.: gathering by the reel in the position best suited to the force or direction of the wind or the inclination of the crop; tilting the fingers so as to alter the height of cut and leave an even stubble; binding the sheaf nearer to or farther from the butt end, to suit long or short crops, and throwing the machine in or out of gear.

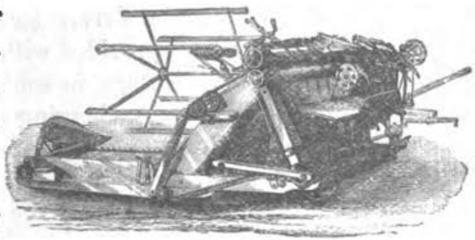


Fig. 122.

Wood's Harvester.—Mr. Wood claims as the special feature of this machine the security of the knot and the uniformity of the sheaf in a thick or thin crop, which is obtained by automatic regulations, so that the required bulk of grain must have come up the elevator before the pressure forces out the lever to make the sheaf. The grain is straightened by the action of the packers as it enters the binder, so that the sheaves are regular and compact, and the driver is relieved from all care regarding the binding apparatus, which performs its work entirely without assistance. The whole of the knotting gear is above the frame and exposed to view, and the parts are so distributed that they are easy of access for the purposes of adjustment and repairing.

Howard's String Sheaf-binding Reaper.—In this machine, Fig. 123, the reel for gathering the corn to the knife is driven by a new patented arrangement, and does not revolve when the machine is not cutting, while it can be adjusted by the driver for short, long, or inclined grain. It is also provided with an adjustable divider, which is an advantage in working a difficult crop. In order to avoid any clogging of the knotting mechanism, the needle arm, instead of binding the sheaves in its descent, grips and binds them in its ascent. This method of working the needle arm is known in the United States as the Appleby plan, and is adopted in nearly all the sheaf-binders except Wood's harvester, which is on the Wood system. The cut grain is carried up between double canvas elevators, and is delivered by the butting appliance to the sheaf packers, which also work upwards from beneath the table, the compressors being adjusted to regulate the size of the sheaf. A spring rod takes up the slack twine as the needle-arm descends.

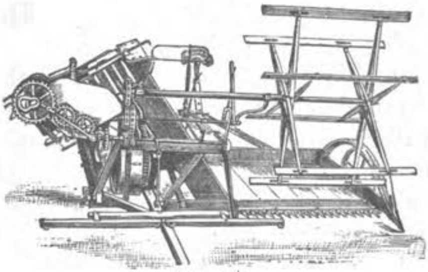


Fig. 123.

Samuelson's Sheaf Binder.—Fig. 124, shows a view of the twine sheaf-binder of Messrs. Samuelson & Co., which gained a special silver medal at the trials of the Royal Agricultural Society at Derby, in 1881.

The gathering reel can be raised or lowered to meet the requirements of the crop. It is driven directly by

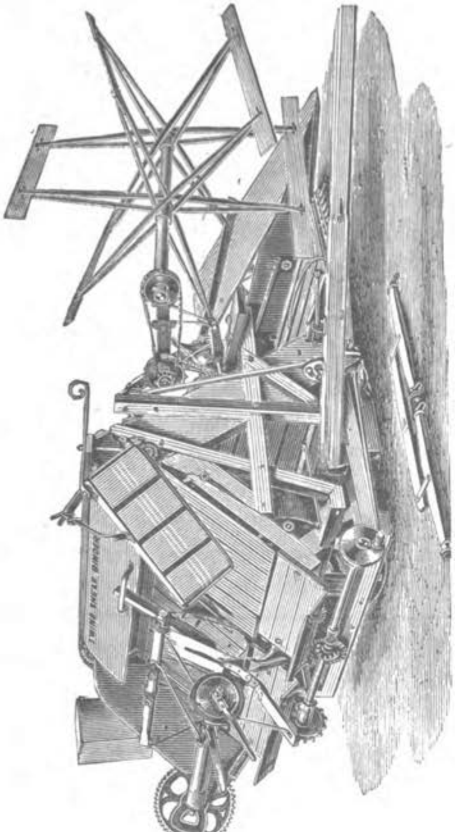


Fig. 124.

chain-gear from the main wheel, and is supported by cross-bar framing.

The elevator consists of two endless aprons with cross-bars similar to the platform shown in the engraving.

As the grain comes over the top of the elevator side on to the binder, a short endless apron with cross-bars of wood rectifies the butt end of the sheaf, directing it to the packing arms so as to be tied in the proper place.

The binder platform is a regular incline from top to bottom. The grain as it comes down from the elevator is protected from wind by a storm-screen, in the rear of which is a rectangular box for holding the twine.

The packing apparatus is beneath the binder platform, and consists of two arms with forked extremities, which work alternately through two slots in the platform, one on each side of the binder-arm. In the middle slot the binder-arm is seen, with the forked extremity of the rear packer-arm on the other side, whilst the point of the other packer is just perceptible above the opening in which it works. The two curved fingers or claws below, against which the sheaf is packed, are fixed one on each side of a sustaining bar in connection with a spring device for weighing or measuring the size of the sheaf.

The needle-arm is so timed as to rise with the last stroke of the packer-arm, which overcomes the resistance of the fingers or the measure of the size of the sheaf, the object being to effect a complete separation of the grain enclosed in the sheaf from that coming down from the elevator.

The binding apparatus consists of a knotter-shaft and hook, with a movable jaw centred on a pin in the head, and extending back so as to open and close by means of cams and cam-gear.

The sheaf is discharged partly by two arms and partly by its own weight. The moment the knot is formed the supporting boards fall down, when the weight of the sheaf draws the knot tight, the two discharging arms acting conjointly. In discharging the sheaf they make a complete rotation.

CHAPTER XX.

HAYMAKERS.

As the work of haymaking has to be done timeously and with speed, the value of a first-class haymaker not liable to get out of order cannot be overrated. In many cases its use in a single season more than repays its cost.

In bright weather the haymaker may follow close behind the mowing machine, strewing and scattering the grass about in all directions with an evenness that sets the work done by hand at defiance. Two or three turns of the tedder make the grass into hay ready for the horse-rake, another modern implement which does the work of half-a-score of hands.

Howard's "Simplex" Haymaker.—This (Fig. 125) is a single-action machine which effectually meets the requirements of those hay growers who need a machine of the kind within the power of one light horse. As will be seen from the illustration, the gearing is of the simplest character, all being open to inspection, as well as easy to get at. A guard which is placed over the gearing prevents the grass falling on the pinion-wheel. The two fork-barrels with four rakes each are mounted on a solid continuous axle, which gives great rapidity to the machine.

The levers for putting the machine in and out of gear are so placed that there is no danger in shifting them whilst the machine is in motion.

The forks, when at their lowest working point, are as nearly as possible in line with the centre of the travelling wheels, in order to adapt the machine for working over ridges and furrows.

The "lantern" or open gearing on the travelling

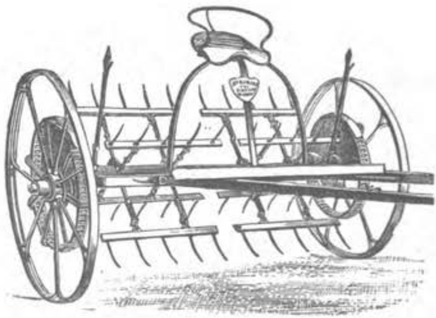


Fig. 125.

wheels is an extension of the principle so successfully employed by J. and F. Howard in their simplex mowers and reapers, and is also advantageous when applied to haymakers, which with ordinary gearing are liable to be choked by grass-seeds and hay.

The custom of making hay by the use of the back or turning action only is in many districts displacing the old method of tedding or tossing, as it is found that when grass is cut by a mowing machine it is generally so well laid for drying in the swathe that nothing more than once or twice turning is needed.

Ransome's "Star" Haymaker.—This double-speeded back-action haymaker (Andrews' patent) differs from the usual "double-action" haymakers in not having any forward or overhead motion, instead of which it has *a fast as well as a slow* back action.

The separating and distributing of the grass from the swathe is done by means of the fast backward

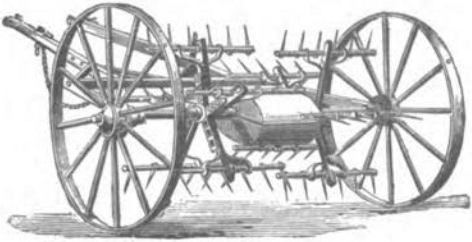


Fig. 126.

action, which throws the hay up behind the machine instead of over it, and in many cases this is quite sufficient, especially where the crops are light and are cut by a machine.

The slow motion for turning the hay is especially effective, as the lines being straight do not slip over the green parts which lie at the bottom, and the hay is left very light and hollow. The tines can be set more or less pitching to suit any crop.

This haymaker has a straight wrought-iron axle and wrought-iron wheels 4 feet 6 inches high. The gearing, protected by a close case, is securely placed in the centre of the machine. Both rake-barrels revolve when turning at the headlands, and make several revolutions after the horse stops, thereby clearing a space to start again. This haymaker works quite as well over ridge and furrow as on level ground, and the draught is very light.

CHAPTER XXI.

HORSE-RAKES.

These, "once a rough class of implements, are now admirably made tools. The teeth are constructed of steel, and their form has received great attention with the object of collecting large loads while giving a loose, light discharge. They are also made adjustable, so as to lightly skim or closely rake the ground at pleasure. By the adoption of a balanced rocking frame, locked when at work and free when raised, the effort of lifting has been reduced to a minimum, while seats have been added, together with an automatic delivery under the control of the driver." (Pidgeon.)

Howard's Self-acting Horse Rakes.—In these rakes, Fig. 127, the arrangement for emptying the load is extremely simple, the driver if riding merely having to touch a lever with his foot, and if walking simply to take hold of a lever with his hand, when two brake-clips grip the tyres of the travelling wheels and raise the teeth. No exertion is required, inasmuch as the power of the horse is used instead of that of the driver. When the foot is removed from the lever the clips are immediately released, and the teeth fall at once into raking position.

The teeth of these rakes are made of wrought tempered steel, fitted and tapered, so that lightness and strength are combined. They are of great capacity, and made in the best form for collecting the crop without compressing it; and they are so suspended that they have full liberty to fall into hollows or furrows, and to adapt themselves to the irregularities of

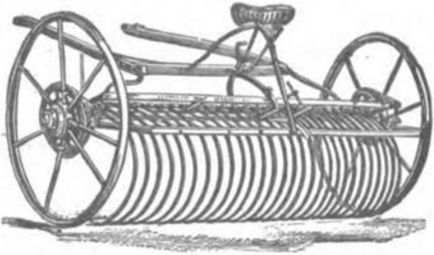


Fig. 127.

the surface, and, being coupled, they rake clean and are not liable to get loose, out of place, or out of shape.

These rakes are made with a pole instead of shafts for countries where animals are yoked in this fashion.

American Horse Rakes. — These hay collectors, Fig. 128, are very convenient for gathering hay into

Fig. 128.

winrows. They are made both in wood and in steel by the Bristol Waggon Works Company, and being cheap as well as useful they are extensively used.

Drag Rake on Wheels.—This is an improved stubble rake, and is made for attaching to reapers, for raking after the machine has passed. It makes tidy, clean stubble.

CHAPTER XXII.

GRINDSTONES AND KNIFE SHARPENERS.

A GOOD grindstone is of immense convenience on the farm, especially during hay and corn harvests, for

Fig. 129.

sharpening and grinding scythes, hay-knives, and reaper-knives, &c.

One of the best Newcastle grindstones is illustrated in Fig. 129. The stone, which is mounted on an iron frame, and runs in brass bushes, is worked by treadle, and is fitted with water barrel and tap. Instead of the

Fig. 130.

latter, the stone can be mounted to run in water tubs, as in Fig. 130.

Samuelson and Co., Banbury, now manufacture grindstones well adapted for the purpose of sharpening the knives of grass-mowers and reaping machines.

These stones are of the best quality, well mounted on strong frames, and supplied with both crank-handle and treadle, so as to be worked by the hand or with the foot.

One of them, mounted in wooden trough, is shown in Fig. 130. The stone is 24 inches diameter.

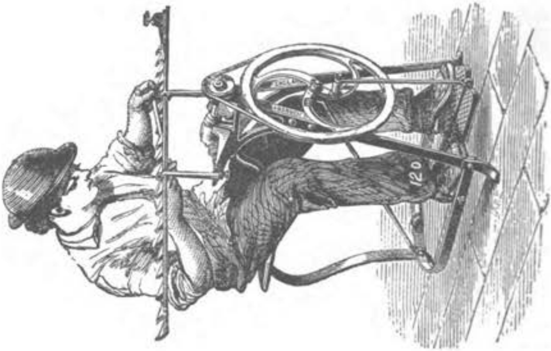


Fig. 132.

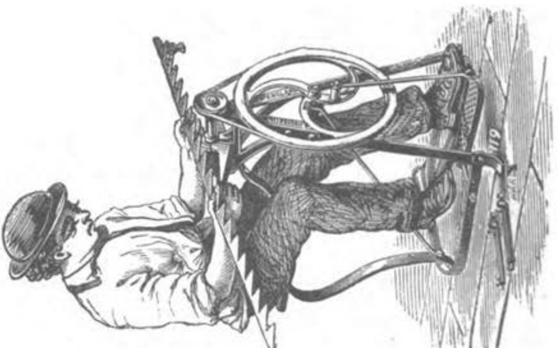


Fig. 131.

The Patent Knife Grinding, Sharpening, and Holding Machine, Manufactured by R. Hornsby and Sons, Limited, is shown in Figs. 131 and 132. The knife grinder is a wonderfully handy little machine, and supplies a want long felt by users of reaping and mowing machines, in which so much depends on the knives being kept properly sharp. It consists of a light frame, with small grindstone, wheel, and treadle, and is most convenient for sharpening the knife-sections in the field. Fig. 132 shows the machine with the addition of two knife rests, for use when it is desired to sharpen with the file or stone by hand.

CHAPTER XXIII.

CARTS AND WAGGONS.

These, like most other agricultural machines, vary in their form and construction, according to the nature of the district or country and the purpose for which they are used.

Carts and Waggons.—We have no space here to enter at length into the question of wheel carriages. That carts possess many advantages over waggons is now pretty generally acknowledged, and is proved by the fact that wherever any large amount of work has to be done carts only are employed, as a horse when drawing singly will do half as much more work than when acting with another. Three horses will certainly do more work in single-horse carts than four in two-horse carts; and when the work is regular, and along tolerably even roads, there is a great saving in horse-power with carts as compared with waggons.

In a cart the horse partly bears and partly draws his load, and thus economises power; whereas the animals yoked in a waggon expend their power in pulling only, the whole weight of the load being distributed over the four wheels. In going down-hill, however, the load on the cart-horse's back is somewhat of a disadvantage, unless the carter is careful to have the load well balanced.

It was proved in the trials instituted on this point by the Royal Agricultural Society at Bedford, in 1874, that the mean draught of carts, both per ton of gross load and per ton of useful load, was much less than in waggons. In these trials pair-horse waggons were compared with single-horse carts, the former being loaded with 45 cwt. and the latter with 20 cwt. of roots. The result, as tested by the dynamometer, was, that the average mean draught per ton of useful load of the three waggons when travelling along the road was found to be 68·1 lbs. as compared with 51·4 lbs. in the carts, the difference in favour of the carts being 16·7 lbs., or 24·5 per cent. On arable land the waggons showed a mean draught per ton of useful load of 295·2 lbs. as compared with 201 lbs. in the carts, thus showing a still greater difference of 94·2 lbs., or 31·9 per cent. Taking the average of these percentages, and assuming that the travelling on road and on the fields are equal, there is an actual loss of horse-power in transport amounting to 28·2 per cent. on a farm where waggons are used instead of carts.

Carts.—One of the most useful vehicles for agricultural purposes is the single-horse Scotch cart. It carries from 18 to 22 cwt., and consists, besides the axle and wheels, 4½ feet in diameter, of a rectangular body and two shafts, with raised sides inclined outwards, and additional "top-sides," movable at pleasure.

In Scotland this cart is in universal use for farm purposes. Though usually drawn by one horse, two horses, one in front of the other, are sometimes yoked to it when the weight is increased or the road hilly, a plan which it is not advisable to adopt as it leads to a wasteful expenditure of animal force, with less satisfactory results than if two single-horse carts were employed.

When a bulky load, such as corn in the straw or hay, is to be carried, the area of the cart is augmented by placing a sparred wooden frame upon the sides, beyond which it projects.

A "tilt" Scotch cart is so constructed that by withdrawing a pin in the forepart of the cart, the body may be tilted up and its contents discharged behind without unyoking the horses.

A good general purpose farm cart is that made by Crosskill of Beverley, and shown in Fig. 133. It is

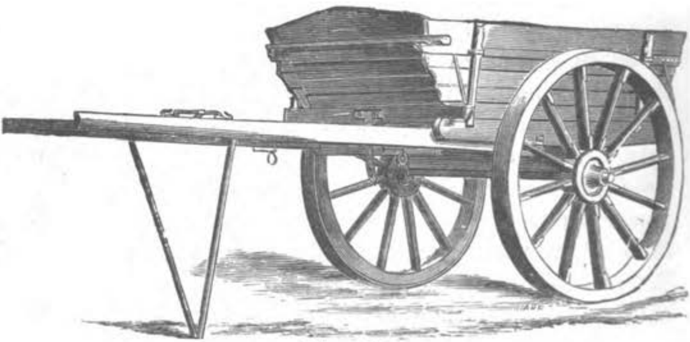


Fig. 133.

made with strong oak framing, plank sides, portable top-boards, and tipping-swords, and is usually fitted with iron naves to wheels, but can be had with wood naves if required.

Fig. 134 shows the same cart, with top-boards removed and harvest-ladders in place. Other forms of harvest-ladders may be used.

Of carts for special purposes there are many varieties. Haunam's Improved Harvest Cart, made by Crosskill, is shown in Fig. 135. This is a long cart with low sides, for harvest-work only, and is made low expressly for the purpose of carrying hay, corn, &c.

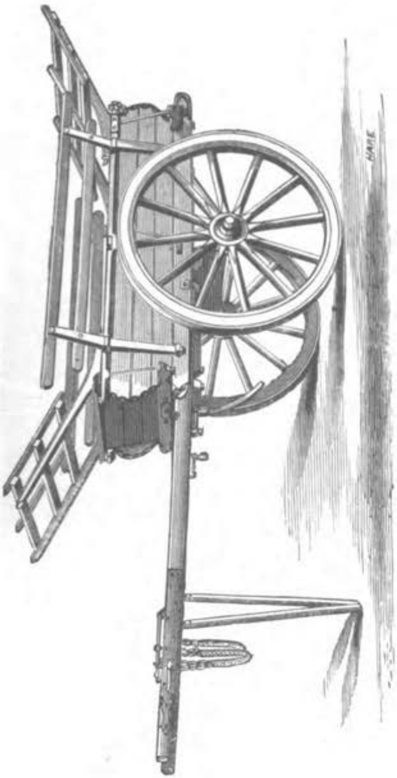


Fig. 134.

The wheels have convex tires, which does not injure grass land like the flat tire with sharp edges.

Crosskill's Improved Spring Cattle Cart, Fig. 136, is constructed with movable cover, arranged so that cattle can walk in at one end and out at the other, and is fitted with improved regulating screen lever to enable the body to be kept level when travelling either up or down hill.

A light and useful crank-axle cart, Fig. 137, is made

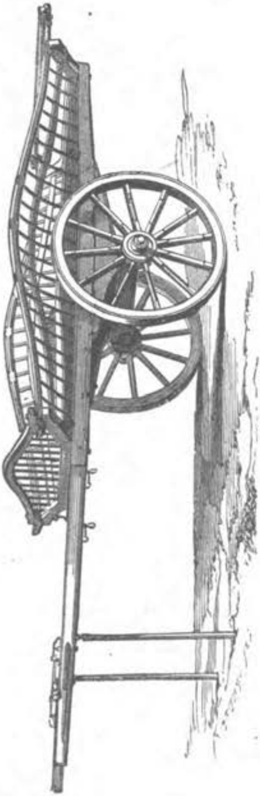


Fig. 135.

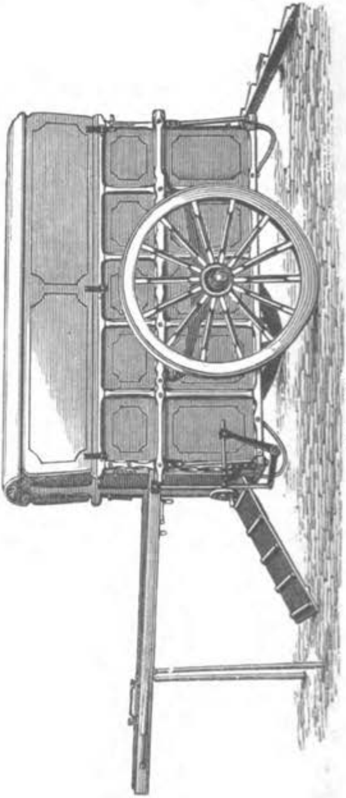


Fig. 136.

by the Bristol Waggon Works Co., for carrying sheep, pigs, &c. The body of the cart is low on the ground, and convenient for loading. It is fitted with high sides and tailboard, which when let down enables the animals to walk up into the cart; and is mounted on patent axle and three springs.

Various other kinds of carts are more or less used by agriculturists, but they are not of sufficient importance to require special notice here.

Waggons.—Although, as we have attempted to show, carts are more economical than waggons, the latter are preferred by many farmers, especially for conveying heavy loads to a considerable distance.

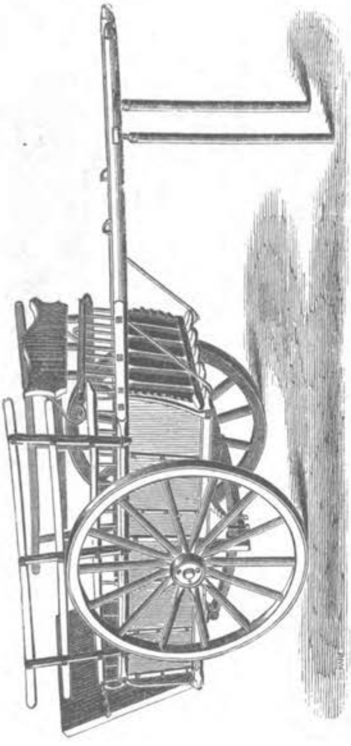


Fig. 137.

In England the four-wheeled waggon is the principal vehicle for carrying farm produce of every kind. It is generally drawn on roads by two horses yoked abreast; but when its use is confined to the farm, two, three, or even four horses are yoked tandem, giving considerably less effect. The fore wheels of the waggon are smaller than the hind wheels, and their axle is swivelled to the body of the waggon to facilitate turning.

Fig. 138 shows a strongly made waggon for farm purposes, by the Bristol Waggon Works Co. It is made of oak framing, with plank sides 1½ inches

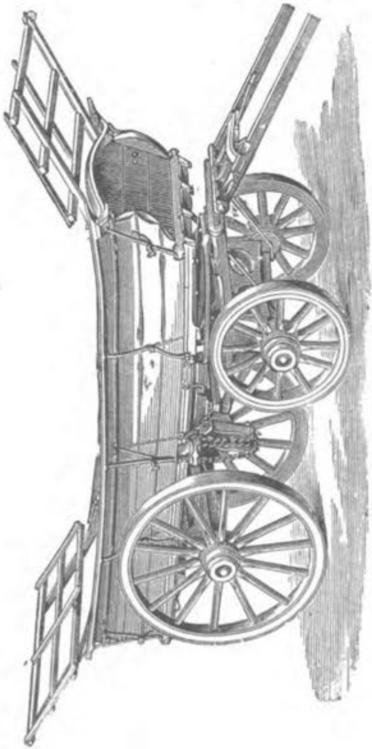


Fig. 138.

thick. The front wheels are made to lock under the body, so that the waggon may be turned in its own length. It is fitted with drag-shoe, tie-chain, &c., complete.

INDEX.

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In the Press.

AGRICULTURAL SURVEYING.

BY PROFESSOR JOHN SCOTT.

*** *Being the Seventh and Concluding Volume of the Farm Engineering Text-Books.*

CONTENTS.

SCOTT'S FARM ENGINEERING TEXT-BOOKS

VII.

AGRICULTURAL SURVEYING

A

PRACTICAL TREATISE

ON

LAND-SURVEYING, LEVELLING, AND SETTING-OUT; AND ON MEASURING AND ESTIMATING QUANTITIES, WEIGHTS, AND VALUES OF MATERIALS, PRODUCE, STOCK, ETC. ETC.

PREFACE.

THIS, the seventh volume of the "Farm Engineering Text-Books," brings the series to a close.

The introductory chapters of this volume treat of the different methods of Land Surveying by the chain; of the instruments used in chain surveying; of noting the measurements; and of plotting and calculating the content. Then follow chapters on Surveying by the Theodolite, and on Levelling. The peculiar system upon which the United States Public Lands are surveyed is explained, in the interest of the large body of immigrant farmers and young men who annually leave our shores for America; and a chapter is devoted to the division and laying out of lands.

The principles of estimating weight, quantity, and values are likewise given as fully as the extent of the work will allow.

Tables of Imperial Weights and Measures are appended, with their Metric equivalents.

CONTENTS.

AGRICULTURAL SURVEYING.

CHAPTER I.

LAND SURVEYING.

THE object of land surveying, as usually understood, is the determination of the area and shape of a tract of land.

A survey of this kind usually embraces—

(1.) An examination of a tract as to
Extent,
Contour,
Divisions, &c.

(2.) A plan showing the said features, or some of them.

The duties of a land-surveyor, however, frequently extend beyond making a plan and giving the superficial area; such as disputed boundaries, exchange and division of land, diversion and improvement of roads, as well as the measurement of all kinds of materials and of work performed, &c.

Methods of Land Surveying.—There are but two methods employed in surveying, viz.—

(1.) That by distances and offsets, and
(2.) That by triangles or polygons.

That by distances and offsets is the more simple for complicated objects, and is suitable to detail operations only, as the position of fences, buildings, &c. It is always based upon the system of triangles.

In surveying by triangles the system of triangles is used. There is a system of surveying by polygons, but it is only a modification of the system of triangles.

Land surveying is further divided into two classes, according to the instruments, &c., employed:—

First, by the chain, or by the chain and cross only;

Second, by the chain, and the use of the theodolite or other instrument for measuring angles; and

Third, by trigonometry, which is chiefly performed by the theodolite and logarithmic tables.

The latter is seldom required in agricultural surveying.

The mode of proceeding adopted by land-surveyors varies much with the extent and character of the country to be surveyed; in fact, under the same circumstances, two different surveyors will perform their work very differently from each other, and with different kinds of instruments, although each may be equally accurate in his results.

And in all the methods of land surveying there are three stages of operations:—

1. *Measuring* certain lines and angles, and *recording* them.
2. *Drawing* them on paper to some suitable scale; and
3. *Calculating* the contents of the surface surveyed.

CHAPTER II.

INSTRUMENTS USED IN CHAIN SURVEYING.

Gunter's Chain.—This is the instrument most commonly used in land measuring. It is 66 feet, or 4 rods long, and is divided into 100 links, each link being 7·92 inches long.

The reason for having the chain of 66 feet or 100 links is owing to its convenient relation to the standard units, a chain being the $\frac{1}{80}$th part of a mile; the $\frac{1}{10}$th

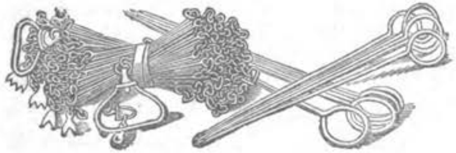


Fig. 1.

part of a furlong, and a square chain being the $\frac{1}{10}$th part of an acre. Ten square chains therefore make one acre, and the computation of areas is thus greatly facilitated.

The links being decimal parts of the chain is also a great advantage, as they may be so written down—10 chains and 80 links, for example, being 10·80 chains; and all the calculations respecting chains and links can then be performed by the common rules of decimal arithmetic.

Every tenth link in the chain is marked by a piece of brass, having one, two, three, or four points, corresponding to the number of tens which it marks, counting from the nearest end of the chain. The middle or fiftieth link is marked by a round piece of brass.

Steel wire is better than iron for surveying chains, owing to its greater strength and stiffness. The rings and eyes which unite the links of a chain are better to be welded than the old way of merely folding the ends. The elliptical form of eye is the best.

The chain should be kept free from bends or crooks in the links, the rings and eyes all clean; and the length should be accurately and regularly tested. It is prudent to test the length of a chain on every occasion of using it, even though the joints are welded.

Arrows.—Ten arrows usually accompany the chain. They are about a foot long, made of stout iron wire sharpened at one end and bent into a ring at the other. Pieces of red and white cloth are tied to their heads, so that they can be easily found in grass, dead leaves, &c. For carrying in the hand they should be strung on a ring which has a spring catch to restrain them.

Signals usually consist of a pole, to be seen at any necessary distance, and they vary in length from 9 feet upwards. They must be planted exactly over the station they are intended to mark, and truly vertical, by looking at it from a little distance, or by holding a plumb line between it and the eye, when it should be looked at from two points as nearly as possible perpendicular to each other.

To render poles conspicuous they should be painted black and white alternately in lengths, or have flags (red or white) attached to them. A red flag is of a colour not so common as white, but white gives a brighter light than red, and, but for other objects, should be visible at the greatest distance.

The most important point with reference to signals is, the pole should be placed truly vertical, so that if only the top of it can be seen it may cause no error.

How to Chain.—The manner of using the chain should be carefully attended to, so that its length may be always correctly pointed off by the chain-leader, as thus:—

The line having been previously poled out, the surveyor standing at the station point holds one end of the chain, the assistant with the other end in his right hand and the arrows in his left hand, which are transferred one by one into the right hand. On arriving at the extent of the chain, he turns partly round, holding the arrow perpendicular at the end of the chain, looking towards the surveyor, who springs the chain until it is in a straight line with the fore object, then, by motion of the head or hand, directs the leader to move the arrow accordingly, until it is in the proper point of the line and the chain fairly stretched out; the arrow is then to be fixed in the ground and the chain remain at rest until the surveyor has taken all the offsets and remarks necessary, and at his signal proceed on to the next length, and so continuing until the whole ten arrows are fixed or transferred into the surveyor's possession. The leader then proceeds, without any pins, adjusting the chain in the line, which must remain at rest until the surveyor arrives at that end and puts one down, delivering the nine arrows remaining to the leader, each time carefully counting them at every change, and also at the end of every line, to prove that no mistake has occurred by dropping one or by false entry.

The leader should be trained to keep the line by a back object—that is, by placing himself in a line with the arrow last put down and the mark or pole at the station, or some distant object that may accidentally be in line. It saves much time and labour when the chainman is made to keep or pole out a line truly.

Measuring-tapes.—Though the chain is most usually employed for the principal measurements, a tape-line, divided on one side into links and on the other side into feet and inches, is more convenient for taking short lengths, as in measuring offsets, &c. Tapes will all vary in length by the moisture in the air, and hence are not free from errors. Those made of best strong linen wear well, and keep to standard better than any others.

Fig. 2.

Offset-staff.—This is also an important accompaniment to the chain, being convenient for measuring short offsets. It is usually ten links long, painted white, with each link marked by a black painted ring, and the ring numbered 1, 2, 3, &c. The bottom of the rod is shod with an iron spike and the top has a stout open ring, as thus ♀, to force or draw the chain through the bottom part of a fence.

Cross-staff.—A number of convenient instruments of simple form, known as the cross-staff or the surveyor's cross, are in use for setting out perpendiculars by lines of sight, crossing each other at right angles; and a temporary substitute for them is easily made by sticking a pin in each corner of a square piece of board, and sighting across these in the direction of the line and at right angles to it.

The commonest form of cross-staff is that represented in Fig. 3. It consists of a block of wood (which may be of any shape) having in it two saw-cuts, made very precisely at right angles to each other, and with centre-bit holes made in the bottom of the cuts to assist in finding the objects. This block is fixed on a pointed staff, on which it can turn freely, and which should be precisely 8 links ($63\frac{1}{3}$ inches) long, for the convenience of short measurements.

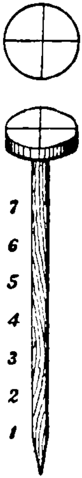


Fig. 3.

To test the accuracy of the instrument, sight through one slip to some point, A (Fig. 4), and place a stake, B, in the line of sight of the other slip. Then turn its head a quarter of the way around, so that the second slip looked through points to A. Then see if the other slip covers B again, as it will if correct. If it does not do so, but sights to some other point, as B′, the apparent error is double the real one, for it now points as far to the right of the true point, C, as it did before to its left. The invaluable principle of this test is that it doubles the real error and makes it twice as easy to perceive and correct it.

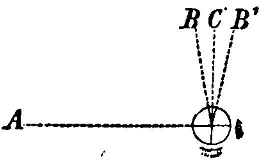


Fig. 4.

To use the cross-staff to erect a perpendicular, set it at the point of the line at which a perpendicular is wanted. Turn its head till, on looking through one saw-cut, you can see the ends of the line. Then will the other saw-cut point out the direction of the perpendicular, and thus guide the measurement desired.

There are many improved forms of cross-staffs. Fig. 5 shows one of these. It is made of plain brass, with centre axis and divided circle to take any angle. A compass is sometimes attached to this cross-staff head.

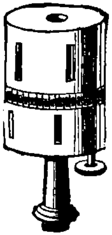


Fig. 5.

Optical Square.—For measuring long offsets and perpendiculars this instrument (Fig. 6) is now very generally used.

Fig. 6.

It is a small circular box containing a strip of looking-glass, from the upper half of which the silvering is removed. This glass is placed so as to make precisely half a right angle with the line of sight, which passes through a slit on one side of the box, and a vertical hair stretched across the opening on the other side, or a mark on the glass.

Another form of the optical square contains two glasses fixed at an angle of 45°, and giving a right angle, or reflecting 90° on both hands.

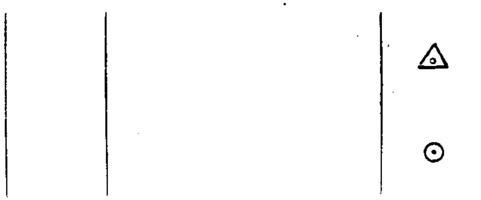
CHAPTER III.

ON NOTING THE MEASUREMENTS.

Keeping the Field Notes.—In all the methods of surveying, the measurements, together with various incidental observations, are recorded after some established system in what are called *field notes*, and from these the results of the survey are afterwards plotted to a convenient scale.

In chain surveying the most simple method of keeping the field-book is to make a *sketch* of the field, as nearly correct as the unassisted hand and eye can produce, and note down on it the lengths of all the lines, as in Fig. 24. But where many other points require to be noted, such as where fences, or roads, or streams are crossed in the measurement, or any other additional particulars, the sketch would become confused and be likely to lead to mistakes in the subsequent plotting of it. The following is, therefore, the usual method of keeping the field notes. A long narrow book is most convenient for it.

Draw two parallel lines about an inch apart from the bottom to the top of the field-book, as in the margin. This column, or pair of lines, may be considered to represent the measured line split in two, its two parts being thus separated, an inch apart, merely for convenience, so that the distances measured along the line may be written between these halves.



Hold the book in the direction of the measurement. At the bottom of the page write down the name or number or letter which represents the station at which the survey is to begin.

A "station" is marked with a triangle or circle, as in the margin. The latter is more easily made.

The station from which the measurements are made is usually put on the left of the column, and the station which is measured to is put on the right.

But it is more compact, and avoids interfering with the notes of "offsets" to write the name or number of the station in the column, as in the margin.

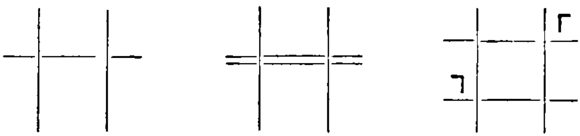
The measurements of different points of a line are written above one another. The numbers all refer to the beginning of the line, and are counted from it.

	⊙	to B	B	B
				400
	562		562	250
				100
From A	⊙		A	A

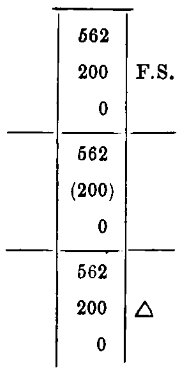
The end of a measured line is marked by a line drawn across the page above the numbers of the measurements which have been made.

If the chaining does not continue along the adjoining line, but the chain-men go to some other part of the field to begin another measurement, two lines are drawn across the page.

When a line has been measured, the marks ┌ or ┐ are made to show whether the following line turns to the right or to the left.



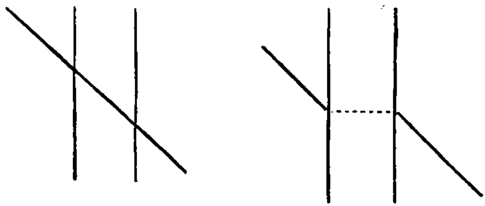
When a mark is left at any point of a line, with the intention of coming back to it again in order to measure to some other point, the place marked is called a *false station*, and is marked in the field-book F.S., or has a line drawn around it to distinguish it, or has a station mark △ placed outside of the column, to the right or left, according to the direction in which the measurement from it is to be made. Examples of these three modes are given in the margin.



A false station is named by its position on the line where it belongs; as thus, "200 on 562."

When a gate occurs in a measured line, the distance from the beginning of the line to the side of the gate first reached is the one noted.

When the measured line crosses a fence, brook, or road, &c., they are drawn on the field notes in their true direction as nearly as possible, but not in a continuous line across the column, as in the first figure in the margin, but as in the second figure, so that the two



parts would form a continuous straight line, if the halves of the "split line" were brought together.

It is convenient to name the lines in the margin as being sides, diagonals, proof-lines, &c.; but in many cases they are denoted by numbers. When two or more lines proceed from the same station, they are distinguished by a smaller figure over, thus 1^2 or 1^3, denoting that a second or third line commenced from that point or station.

Particular attention should be paid in showing the fences, to which field they belong, and where they change, at which point always take an offset. If there is a ditch to the hedge or other fence, the ditch is always the boundary, and is noted in the field-book thus TLL. The line denotes the ditch, the letter T shows the side on which the fence belongs.

When the ditch is next the chain, the offset is taken at right angles from the chain to the edge of the ditch, and when the ditch is outside, the offset is taken to the middle of the fence with the offset staff, and six or seven links added to it, as general allowance for the ditch, about 4½ feet from the middle of the fence.

When there is no ditch on either side, the offset must then be taken to the centre of the fence, and noted in the field-book thus ——I—— .

A paling fence is described thus — — — —, excepting when it is the boundary next a road, in which case there is sometimes a ditch outside. Wire fences are distinguished by a spiral line ~~~~~~~~, and walls or dykes by two parallel lines ═══. Footpaths and roads without fences are shown by small dotted lines . . . . . .

CHAPTER IV.

PLOTTING A CHAIN SURVEY.

The field work being completed, the figure of the tract surveyed is reproduced upon a diminished scale by what is termed *plotting*, or platting.

A *plot* of a survey is a skeleton or outline map. It is a figure similar to the original, having all its angles equal and its sides proportional. Every inch on it represents a foot, a yard, a rod, a mile, or some other length on the ground, all the measured distances being diminished in exactly the same ratio.

The only instruments absolutely necessary for this are a straight ruler and a pair of dividers or compasses. Others, however, are often convenient, and may be briefly noticed.

Parallels.—The readiest mode of drawing parallel lines is by the aid of a triangular piece of wood and a ruler. Let A B (Fig. 7) be the line to which a parallel is to be drawn, and C the point through which it must pass. Place one side of the triangle against the line, and place the ruler against another side of the triangle. Hold the ruler firm and immovable

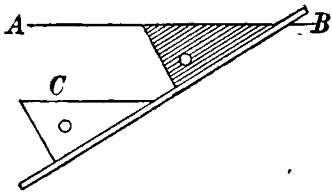


Fig. 7.

and slide the triangle along it till the side of the triangle which had coincided with the given line passes through the given point. This side will then be parallel to that given line, and a line drawn by it will be the line required.

Another easy method of drawing parallels is by means of a T-square, an instrument very valuable for many other purposes. It is nothing but a ruler let into a thicker piece of wood very truly at right angles to it. For this use of it, one side of the "cross-piece" must be even or "flush" with the ruler. To use it, lay it on the paper so that one edge of the ruler coincides with the given line A B. Place another ruler against the cross-piece, hold it firm, and slide the T-square along till its edge passes through the given point C, as shown by the lowest part of the diagram (Fig. 8). Then draw by this edge the desired line parallel to the given line.

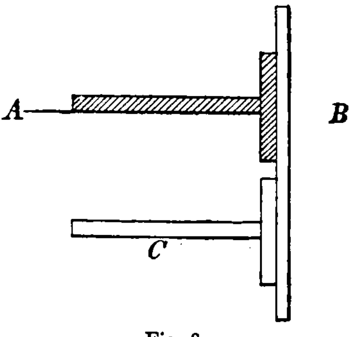


Fig. 8.

Perpendiculars.—These may be drawn by the various problems given in geometry, but more readily by a triangle which has one right angle.

Place the longest side of the triangle on the given line, and place a ruler against a second side of the triangle, as in Fig. 9. Hold the ruler fast, and turn the triangle so as to bring its

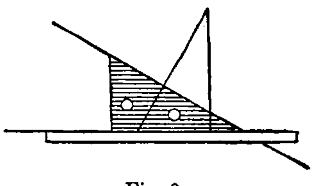


Fig. 9.

third side against the ruler. Then will the long side be perpendicular to the given line. By sliding the triangle along the ruler, it may be used to draw a perpendicular from any point of the line, or from any point to the line.

Perpendiculars are also at times drawn by means of a semicircular protractor.

Drawing to Scale.—The operation of drawing on paper lines whose length shall be a half, a quarter, a tenth, or any other portion of the lines measured on the ground, is called "drawing to scale."

To set off on a line any given distance to any required scale, determine the number of chains or links which each division of the scale of equal parts shall represent. Divide the given distance by this number. The quotient will be the number of equal parts to be taken in the dividers and to be set off.

For example, suppose the scale of equal parts to be a carpenter's common rule, divided into inches and eighths. Let the given distance be 12 chains, which is to be drawn to a scale of 2 chains to an inch. Then 6 inches will be the distance to be set off. If the given distance had been 12 chains and 75 links, the distance to be set off would have been 6 inches and 3-8ths, since each eighth of an inch represents 25 links.

If the desired scale were 3 chains to an inch, each eighth of an inch would represent 37½ links; and the distance of 1,275 links would be represented by thirty-four eighths of an inch, or 4¼ inches.

A similar process will give the correct length to be set off for any distance to any scale.

If the scale used had been divided into inches and tenths, as is much the most convenient, the above distances would have become on the former scale $6\frac{37}{100}$ inches or nearly $6\frac{4}{10}$ inches, and on the latter scale $4\frac{25}{100}$ inches, coming mid-way between the second and third tenth of an inch.

Conversely, to find the real length of a line drawn on paper to any known scale, reverse the preceding operation. Take the length of the line in the dividers, apply it to the scale, and count how many equal parts it includes, multiply their number by the number of chains or links which each represents, and the product will be the divided length of the line on the ground.

Scales.—The choice of the scale to which a plot should be drawn—that is, how many times smaller its lines shall be than those which have been measured in the ground—is determined by several considerations. The chief one is that it shall be just large enough to express clearly all the details which it is desirable to know. A farm survey would require its plot to show every field and building. A State survey would show only the towns, rivers, and leading roads.

Scales are named in various ways. *They should always be expressed fractionally—i.e.*, they should be so named as to indicate what fractional part of the real line measured on the ground the representative line drawn on the paper actually is. It would be better still if the denominator could always be some power of 10, or at least some multiple of 2 or 5, such as $\frac{1}{500}$, $\frac{1}{1000}$, $\frac{1}{2000}$, $\frac{1}{2500}$, &c.

Plots of *farm surveys* are usually named as being so many *chains* to an *inch*.

Maps of *surveys of states* are generally named as being made to a scale of so many *miles* to an *inch*.

Farm Surveys.—If these are of small extent, two chains to one inch (which is $= 2 \times 66 \times 12 = \frac{1}{1584}$ $= 1 : 1584$) is convenient. A scale of one chain to an inch (1 : 792) is useful for plans of buildings. Three chains to one inch (1 : 2376) is suitable for larger farms or estates. It is the scale prescribed by the (English) Tithe Commissioners for their first-class maps.

The choice of the most suitable scale for the plot of a

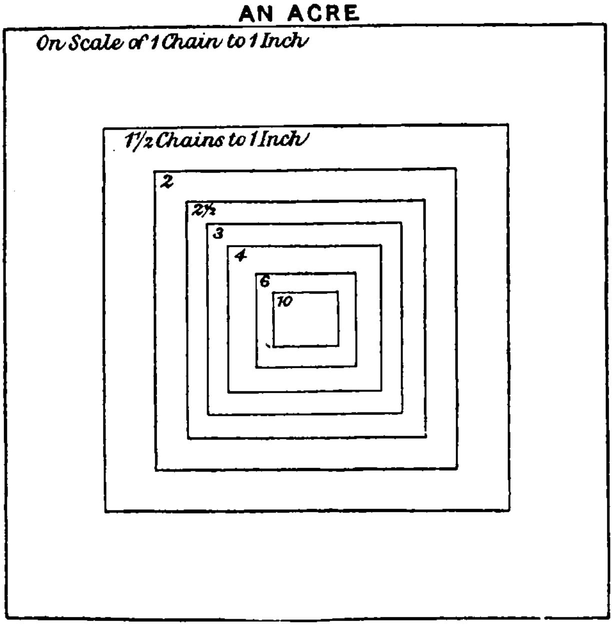


Fig. 10.

farm survey may be facilitated by the preceding figure which shows the actual space occupied by *one acre*, laid out in the form of a square, on maps drawn to the various scales named in the figure.

State Surveys.—On these surveys, smaller surveys, smaller scales, are necessarily employed.

The *Ordnance Survey* of the southern counties of England was plotted on a scale of 2 inches to 1 mile (1: 31,880), and reduced for publication to that of 1 inch to a mile (1 : 63,300). The scale of 6 inches to a mile (1 : 10,560) was adopted for the northern counties of England and for the southern counties of Scotland.

The scale of the parish plans is 1-2500th of the actual length on the ground, and is equal to 25,344 inches to a mile, which is very approximately equal to one square inch to one acre, the square of 1·0018 inch being equal to one acre.

Whatever scale may be adopted for plotting the survey, it should be drawn on the map, both for convenience and reference, and in order that the contraction and expansion caused by changes in the quantity of moisture in the atmosphere may affect the scale and map alike.

Scale omitted.—It may be required to find the unknown scale to which a given map has been drawn, its superficial contents being known.

Assume any convenient scale, measure the lines of the map by it, and find the contents by the methods to be given in the next chapter, proceeding as if the assumed scale were the true one. Then make this proportion, founded on the geometrical principle that the areas of similar figures are as the square of their corresponding sides.

As the contents found *is* to the given content, *so* is the square of the assumed scale *to* the square of the true scale.

TABLE FOR REDUCING OR ENLARGING PLANS BY THE EIDOGRAPH.

Proportion.	Division in Bars.	Proportion.	Division in Bars.
2 to 1	33·333	3 to 2	20·000
3 to 1	50·000	4 to 3	14·285
4 to 1	60·000	5 to 4	11·111
5 to 1	66·666	6 to 5	9·090
6 to 1	71·428	5 to 2	25·000

Reference Books are essential accompaniments to maps or plans, and are of various kinds. Sometimes they merely contain the names and contents of the fields or other parts or divisions, with the state of culture or condition in which they are; in other cases the soil and subsoil are described; but in the most complete cases each farm is described, together with the history of its occupation or improvement under the following heads:—

Name.
Parish.
Extent.
Boundaries.
How let and managed hitherto.
To whom and for how much let at present.
Description of the farm buildings.
Fences, trees.
Ponds, &c., drain outlets, &c.
Content, soil, subsoil, surface, expanse, &c., of each field.
Proportion of land under timber, coppice, &c.

In addition to such a description as the above, some add in the reference book a separate map of each farm, which renders the whole very comprehensive.

CHAPTER V.

CALCULATING THE CONTENT.

Unit of Content.—The acre is the unit of land measurement. A rood contains 40 perches. A perch is a square rod, otherwise called a perch or pole. A rod is $5\frac{1}{2}$ yds., or $16\frac{1}{2}$ ft. Hence 1 *acre* = 4 roods = 160 perches = 4,840 square yds. = 43,560 square ft. *One square mile* = 5,280 × 5,280 ft. = 640 acres. Since a chain is 66 feet long, a square chain contains 4,356 square feet, and consequently ten square chains make an acre.

In different parts of England the acre varies greatly. The *statute acre* contains 160 square perches of $16\frac{1}{2}$ ft., or 43,560 square ft. The acre of *Devonshire* and *Somersetshire* contains 160 perches of 15 ft., or 36 good square ft.; *Cornwall,* 160 perches of 18 ft., or 51,840 square ft.; *Lancashire,* 160 perches of 21 ft., or 70,560 square ft.; *Cheshire* and *Staffordshire,* 160 perches of 24 ft., or 92,160 square ft.; *Wiltshire,* 120 perches of $16\frac{1}{2}$ ft., or 32,670 square ft.; *Scotland* consists of 10 square *chains, each* of 74 *ft.*, and therefore contains 54,760 square ft.; *Ireland* (same as Lancashire). The Irish chain is 84 ft.

When the content of a piece of land (following any of the methods to be explained presently) is given in square links, as is customary, cut off four figures on the right (*i.e.* divide by 10,000), to get it into square chains and decimal parts of a chain; cut off the right figure of the *square chains*, and the remaining figures will be *acres*. Multiply the remainder by 4, and the figures if any, outside of the new decimal point will be *roods*. Multiply the remainder by 40, and the outside figure will be *perches*. Thus—

		A.	R.	P.
86·22 square chains	=	8	2	20
8·250 ,, ,,	=	0	3	12
0·8250 ,,	=	0	0	13

Boundary Lines.—The lines which are to be considered as bounding the land to be surveyed are often very uncertain, unless specified by the title-deeds.

If the boundary be a brook, the middle of it is usually the boundary line. On tide-waters the land is usually considered to extend to low-water mark.

When hedges and ditches are the boundaries of fields, the dividing line is generally the top edge of the ditch farthest from the hedge, both hedge and ditch belonging to the field on the hedge side. This varies, however, with the customs of the locality.

Methods of Calculation.—The various methods employed in calculating the content of a piece of ground may be reduced to four, which may be called *Arithmetical*, *Geometrical*, *Instrumental*, and *Trigonometrical.*

First Method.—Arithmetically. From direct measurements of the necessary lines on the ground.

The figures to be calculated by this method may be either the shapes of the fields which are measured, or those into which the fields can be divided by measuring various lines across them.

The familiar rules of mensuration for the principal figures which occur in practice will be now briefly enunciated.

Rectangles.—If the piece of ground be rectangular in shape, its content is found by multiplying its length by its breadth.

Triangles.—When the given quantities are on one side of a triangle, and the perpendicular distance to it from the opposite angle, the content of the triangle is equal to half the product of the side and the perpendicular.

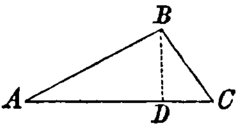


Fig. 11.

When the given quantities are the three sides of the triangle, add together the three sides and divide the sum by 2; from this half sum subtract each of the three sides in turn; multiply together the half sum and the three remainders; take the square root of the product; it is the content required.

Parallelograms, or four-sided figures whose opposite sides are parallel. The content of a parallel equals the product of one of its sides by the perpendicular distance between it and the side parallel to it.

Trapezoids, or four-sided figures two opposite sides of which are parallel. The contents of a trapezoid equals half the products of the sum of the parallel sides by the perpendicular distance between them.

Quadrilaterals, or *Trapeziums,* four-sided figures none of whose sides are parallel.

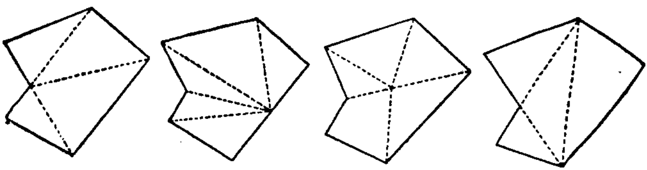
A very gross error often committed as to this figure is to take the average, or half sum of its opposite sides, multiply them together for the area; thus assuming the trapezium to be equivalent to a rectangle with these averages for sides.

In practical surveying it is usual to measure a line across it from corner to corner, thus dividing it into two triangles whose sides are known, and which can therefore be calculated.

Surfaces bounded by irregularly curved lines.—The rules for these will be more appropriately given in connection with the surveys which measure the necessary lines, as will be explained, Part 2, chap. 3.

Second Method. Geometrically.—From measurements of the necessary lines upon the plat or plot.

Division into Triangles.—The plat of a piece of ground having been drawn from the measurements made by any of the methods which will hereafter be explained, lines may be drawn upon the plat so as to divide it into a number of triangles.



Figs. 12, 13, 14, and 15.

Four ways of doing this are shown in the figs. 1. By drawing lines from one corner to the other corner. 2. From a point in one of the sides to the corners. 3. From a point inside of the fig. to the corners. 4. From various corners to other corners. The last method is usually the best. The lines ought to be drawn so as to make the triangles as nearly equilateral as possible.

One side of each of these triangles and the length of the perpendicular let fall upon it being then measured as directed, the content of these triangles can be at once obtained by multiplying their base by their altitude and dividing by two.

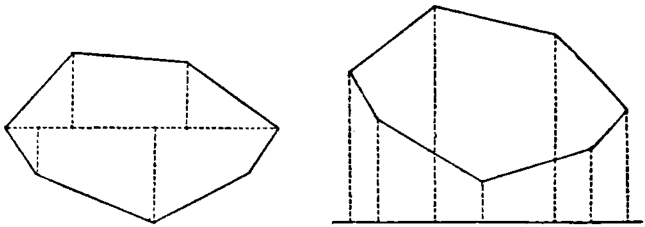
The easiest method of getting the perpendicular, without actually drawing it, is to set one point of the dividers at an angle from which a perpendicular is to be let fall, and to open and shut their legs till an arc described by the other point will just touch the opposite side.

Otherwise, a platting scale may be placed so that the zero point of its edge coincides with the angle, and one of its cross lines coincides with the sides to which a perpendicular is to be drawn. The length of the perpendicular can then at once be read off.

The method of dividing the plat into triangles is the one most commonly employed by surveyors for obtaining the content of a survey, because of the simplicity of the calculations required. Its correctness, however, is dependent on the accuracy of the plat, and on its scale which should be as large as possible. Three chains to an inch is the smallest scale allowed by the Tithe Commissioners for plats from which the content is to be determined.

Some surveyors measure the perpendicular of the triangles by a scale half of that to which the plat is made. Thus, if the scale of the plat be 2 chains to an inch, the perpendiculars are measured with a scale of 1 chain to an inch. The product of the base by the perpendicular thus measured gives the area of the triangle at once, without its requiring to be divided by 2.

Division into Trapezoids.—A line may be drawn across the field, as in Fig. 16, and perpendiculars drawn to it. The field will thus be divided into trapezoids (except a triangle at each end), and their contents can be calculated. Otherwise, a line may be drawn outside the figure, and perpendiculars to it be drawn from such angle, as in Fig. 17. In that case the difference between the trapezoids formed by lines drawn to the outer angle of the fig. and those drawn to the inner angles will be the content. This method is very advantageously applied to surveys by the compass.



Figs 16 and 17.

Division into Squares.—Two sets of parallel lines at right angles to each other, one chain apart (to the scale of the flat) may be drawn over the plat, so as to divide it into squares, as in Fig. 18. The number of

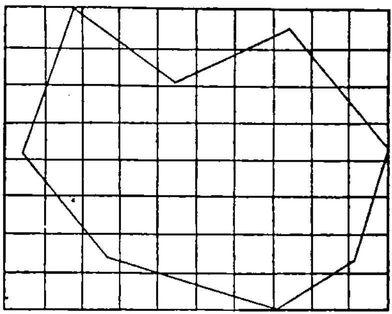


Fig. 18.

squares which fall within the plat represent so many square chains, and the triangles and trapezoids which fall outside of these may then be calculated and added to the entire square chains which have been counted.

Instead of drawing the parallel lines on the plat, they may better be drawn on a piece of transparent "tracing-paper," which is simply laid upon the plat and the squares counted as before. The same paper will answer for any number of plats drawn to the same scale. This method is a valuable and easy check on the results of other calculations.

To calculate the fractional parts, prepare a piece of tracing-paper by drawing on it one square of the same size as a square of the plat, and sub-dividing it by two sets of 10 parallels at right angles to each other, into hundreds. This will measure the fractions remaining from the former measurement as nearly as can be desired.

Divisions into Parallelograms.—Draw a series of parallel lines across the plat at equal distances depending on the scale. Thus, for a plat made to a scale of 2 chains to an inch, the distance between the parallel should be $2\frac{1}{2}$ inches, 3 chains to an inch should be $1\frac{1}{9}$ inch, 4 chains to an inch should be $\frac{5}{8}$ inch. 5 chains to an inch should be $\frac{4}{10}$ inch; and for any scale make the distance between the parallels that fraction of an inch which would be expressed by 10 divided by the square of the number of chains to the inch.

Then apply a common inch scale, divided on the edge into tenths, to these parallels, and every inch in length of the spaces included between each pair of them will be an acre, and every tenth of an inch will be a square chain.

To measure the triangles at the ends of the strips between the parallels, prepare a piece of stout tracing-paper of a width equal to the width between the parallel, and draw a line through its middle longitudinally. Apply it to the oblique line at the end of the space between two parallels and it will bisect the line, and thus reduce the triangle to an equivalent rectangle as at A in Fig. 19. When an angle occurs between two parallels, as at B in the fig., the fractional part may be measured by any of the preceding methods.

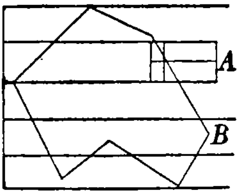


Fig. 19.

Addition of Widths.—When the lines of a plat are very irregularly curved, as in Fig. 20, draw across it a number of equi-distant lines as near together as the case may seem to require. Take a straight-edged piece of paper, and apply one edge of it to the middle of the first space, and mark its length from the end; apply the same edge to the next space, bringing the mark just made to one end, and making another mark at the end of the additional length; so go on, adding the length of each space to the previous ones. When all have been thus measured, the total length, multiplied by the uniform width, will give the contents.

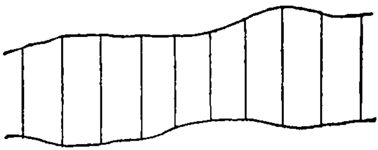


Fig. 20.

Third Method. Instrumentally.—By performing certain instrumental operations on the flat.

Any plain figure bounded by straight lines may be reduced to a single triangle which shall have the same content. This can be done by any instrument for drawing parallel lines.

Special Instruments. — Computing and calculating scales, &c., are also used for finding the content.

Fourth Method. Trigonometrically.—By calculating from the observed angles of the boundaries of the piece of ground the lengths of the lines needed for calculating the content.

This method is employed for surveys made with angular instruments, as the compass, &c., in order to obtain the content of the land surveyed, without the necessity of previously plotting it, thus avoiding both that trouble and the inaccuracy of any calculations founded upon it. It is, therefore, the most accurate method, but will be more appropriately explained under the head of compass surveying.

Logarithms.—The logarithm of a number is the exponent of the power to which it is necessary to raise a fixed number to produce the given number. The fixed number is called the *base.* Thus, in the equation $10^3 = 1000$, 3 is the log. of 1000, the base being 10. Any positive number except 1 may be taken as a base, and for each base there is a corresponding *system of logarithms.* There is therefore an infinite number of systems of logarithms, but only two of them are in general use—the *Napierian* system, whose base is 2·718281828, mostly employed in the higher branches of analysis and in scientific investigations; and the *Common* system, whose base is 10, used in practical computations, where they (the logs.) serve to convert the operations of multiplication and division into the simpler ones of addition and subtraction. (We adopt the latter.)

In trigonometric computations the use of logarithms is almost indispensable.

Computations by means of logarithms are made in accordance with the following principles:—

(1.) The log. of the product of any number of factors is equal to the sum of the logs. of the factors.

(2.) The log. of a quotient is equal to the log. of the dividend diminished by that of the divisor.

(3.) The log. of any power of a quantity is equal to the log. of the quantity multiplied by the exponent of the power; and

(4.) The log. of any root of a quantity is equal to the log. of the quantity divided by the index of the root.

In applying these principles, the logs. needed are taken from tables called tables of logarithms.

The manner of arranging the tables, and also the manner of using them, will be best learned from the explanations which precede each collection of tables.

The following tables will be found useful:—

CHAINS INTO FEET.

Chains.	Feet.	Chains.	Feet.
0·01	0·66	1·00	66·
0·02	1·32	2	132
0·03	1·98	3	198
0·04	2·64	4	264
0·05	3·30	5	330
0·06	3·96	6	396
0·07	4·62	7	462
0·08	5·28	8	528
0·09	5·94	9	594
0·10	6·60	10	660
0·20	13·20	20	1320
0·30	19·80	30	1928
0·40	26·40	40	2640
0·50	33·00	50	3300
0·60	39·60	60	3960
0·70	46·20	70	4620
0·80	52·80	80	5280
0·90	59·40	90	5940
1·00	66·00	100	6600

FEET INTO LINKS.

Feet.	Links.	Feet.	Links.
0·10	0·15	10	15·2
0·20	0·30	15	22·7
0·25	0·38	20	30·3
0·30	0·45	25	37·9
0·40	0·60	30	45·4
0·50	0·76	33	50·0
0·60	0·91	35	53·0
0·70	1·06	40	60·6
0·75	1·13	45	68·2
0·80	1·21	50	75·8
0·90	1·36	55	83·3
1·00	1·52	60	90·9
2·	3·0	65	98·5
3·	4·5	70	106·1
4·	6·1	75	113·6
5·	7·6	80	121·2
6·	9·1	85	128·8
7·	10·6	90	136·4
8·	12·1	95	143·9
9·	13·6	100	151·5

To *reduce links to feet*, subtract from the number of links as many units as it contains hundreds; multiply the remainder by 2 and divide by 3.

To *reduce feet to links*, add to the given number half of itself, and ad d one for each hundred (more exactly, for each 99) in the sum.

To convert decimal fractions of an acre into roods and perches, multiply the decimal first by 4 and then by 40, preserving the same number of decimals in the product.

Examples—

A.	R.	P.	Acres.
			633·357
			4
			1·428
			40
633	1	17	17·120

A.	R.	P.	Acres.
			527·013
			4
			·052
			40
527	0	2	2·080

TABLE

For converting Decimal Parts of an Acre into Roods and Perches.

Perch.	0 Rood.	One Rood.	Two Roods	Three Roods.
0	·000	·250	·500	·750
1	·006	·256	·506	·756
2	·012	·262	·512	·762
3	·019	·269	·519	·769
4	·025	·275	·525	·775
5	·031	·281	·531	·781
6	·037	·287	·537	·787
7	·044	·294	·544	·794
8	·050	·300	·550	·800
9	·056	·306	·556	·806
10	·062	·312	·562	·812
11	·069	·319	·569	·819
12	·075	·325	·575	·825
13	·081	·331	·581	·831
14	·087	·337	·587	·837
15	·094	·344	·594	·844
16	·100	·350	·600	·850
17	·106	·356	·606	·856
18	·112	·362	·612	·862
19	·119	·369	·619	·869
20	·125	·375	·625	·875

Perch.	0 Rood.	One Rood.	Two Roods.	Three Roods.
21	·131	·381	·631	·881
22	·137	·387	·637	·887
23	·144	·394	·644	·894
24	·150	·400	·650	·900
25	·156	·406	·656	·906
26	·162	·412	·662	·912
27	·169	·419	·669	·919
28	·175	·425	·675	·925
29	·181	·431	·681	·931
30	·187	·437	·687	·937
31	·194	·444	·694	·944
32	·200	·450	·700	·950
33	·206	·456	·706	·956
34	·212	·462	·712	·962
35	·219	·469	·719	·969
36	·225	·475	·725	·975
37	·231	·481	·731	·981
38	·237	·487	·737	·987
39	·244	·494	·744	·994
40	·250	·500	·750	1·000

CHAPTER VI.

METHODS OF CHAIN SURVEYING.

Stations.—In surveying there is a preliminary process of choosing suitable stations on the ground —such as will be well seen from each other; and straight lines may be necessary between them.

The principal station-lines may not be sufficient for all the work of the survey, but subordinate lines and stations are easily made out, forming a network of triangles.

The principal stations must be chosen before the survey is begun; they should be well seen from each other, and give a clear straight line for measurement between them.

The subordinate stations and lines are chosen as the work proceeds, with a view to running the lines near the fences, &c.

Marks, or Bench Marks, are made for reference of positions or levels. The most commonly used are wooden stakes or pegs. Care should be taken to place them truly vertical; and if the head of the pin is larger the precise point should be marked upon it by driving in a nail.

Measuring Straight Lines.—The lines or distances to be measured may be either actual or visual. Actual lines are such as really exist on the surface of the land to be surveyed, either bounding it or crossing it, such as fences, ditches, roads, streams, &c. Visual lines are imaginary lines of sight, either temporarily measured on the ground, or simply indicated by stakes at their extremities. If long they are "ranged out," by methods to be hereafter explained.

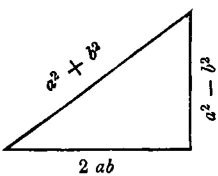
Lines are usually measured with chains, tapes, or rods, divided into yards, feet, links, or some other unit of measurement.

Crooked lines are determined by means of perpendicular offsets measured from different points along the straight line, run as nearly coincident to the crooked line as may be.

When the boundary is irregular, the area of the residual portions which necessarily lie beyond the limits of the triangulation are estimated by the method of taking offsets, which will be fully described in a succeeding chapter of this book.

Triangulation.—Right angles may be set off on the ground by means of the chain.

The setting out of right-angled triangles by the chain, and the reduction of slopes to horizontals, are done by Euclid I. and 47.



In all triangulation (whether by angles or by measured lines), care should be taken to avoid ill-conditioned triangles, or such as have very acute or very obtuse angles. Generally, the surveyor should avoid angles greater than 120° or less than 30°.

An error on the ground generally amounts to an increased error on the paper. The limit of uncertainty, or the probable area of error, will be least when the angles are right angles.

Proof Lines, measured from the corner of each triangle to the opposite side, serve to rectify the other measures of the triangle, and if perpendicular to the side afford a convenient means of calculating upon the ground the area of the triangle.

Measurement of Angles.—The angle made by any two lines—that is, the difference of their directions—is measured by various instruments, consisting essentially of a circle divided into equal parts, with plain sights, or telescopes, to indicate the directions of the two lines. But angles in the field are also determined by the chain. This is done by measuring a *tie-line* from a measured point on one side to a measured point on the other side. By this means the boundaries of a tract may be determined when it cannot be conveniently measured off in triangles.

Horizontal Measurement.—All ground, however inclined or uneven its surface may be, should be measured horizontally and as if brought down to a horizontal plane, so that the surface of a hill, thus measured, would give the same content as the level base on which it may be supposed to stand.

Take, for example, a level field surrounded by a fence in the shape of a perfect square whose side is 10 chains. The area of the field is 10 acres. Through a convulsion of nature a large mound is thrown up in the centre, two or three hundred feet in height, leaving the fences undisturbed. The area of the surface now contained is obviously greater than before, although a surveyor would take no notice of the fact, but would make the area 10 acres, as originally. The necessity for adopting this system of surveying will be seen on considering the diagram.*

* *Knowledge*, November 30th, 1883.

A B C D is a square whose side is 10 chains in length; the mound is shown by dotted lines in the centre. On measuring the line E F along the surface of the ground its length is found to be greater than 10 chains, and this length set off from E would extend to F, distorting

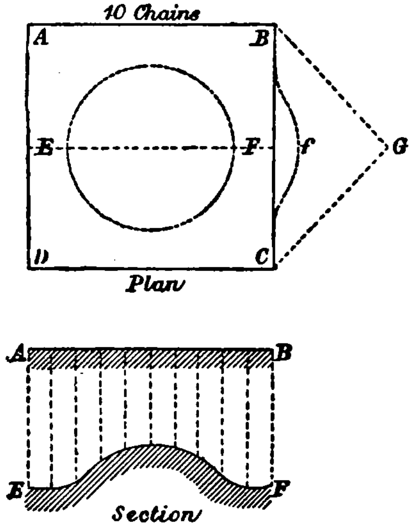


Fig. 21.

the fence, which we know has not changed its position, and bringing it nearer the point C, which we also know is not the case. The necessity for reducing the measurements to a horizontal datum is at once seen.

This is necessary for geometrical reasons, as otherwise in mapping a survey every hilly field or tract would overlap its real boundary.

Horizontal measurement is also justified by the fact that no more houses can be built on a hill than could be on its flat base; and that no more trees, corn, or other plants which shoot up vertically, can grow on it, as is represented by the vertical lines in the section, Fig. 21.

Hilly land is, therefore, always bought and sold in accordance with horizontal measurement.

Chaining on Slopes.—All the distances employed in land surveying must be measured horizontally, or on a level. In chaining uneven or sloping ground, therefore, it is necessary to make certain allowances or corrections. The chain may be held horizontally by the eye,or the slope may be taken by the theodolite, and horizontal distance calculated from the slope of the ground.

When the angle of the slope is measured, the calculation may also be made by a table already prepared. In the following table, the first column contains the angle which the surface of the ground makes with the horizon; the second column contains its slope named by the ratio of the perpendicular to the base; and the third the connection in links for each chain, measured on the slope, *i.e.* the difference between the hypothenuse, which is the distance measured, and the horizontal base, which is the distance desired.

TABLE FOR CHAINING ON SLOPES.

Angle.	Slope.	Correction in Links.	Angle.	Slope.	Correction in Links.
3°	1 in 19	0·14	13°	1 in 4½	2·56
4°	1 „ 14	0·24	14°	1 „ 4	2·97
5°	1 „ 11½	0·38	15°	1 „ 4	3·41
6°	1 „ 9½	0·55	16°	1 „ 3¾	3·87
7°	1 „ 8	0·75	17°	1 „ 3½	4·37
8°	1 „ 7	0·97	18°	1 „ 3¼	4·89
9°	1 „ 6½	1·23	19°	1 „ 3	5·45
10°	1 „ 6	1·53	20°	1 „ 2¾	6·03
11°	1 „ 5¼	1·84	25°	1 „ 2	9·37
12°	1 „ 4¾	2·19	30°	1 „ 1¾	13·40

Surveying by Diagonals.

Surveying by Diagonals is an application of the *first method* of determining the position of a point already shown, to which the student should again refer. Each corner of the field or farm which is to be surveyed is "determined" by measuring its distances from two other points. The field is then "platted" by repeating this process on paper for each corner, in a contrary order, and the "content" is obtained by some of the methods already explained.

The lines which are measured in order to determine the corners of the field are usually *diagonals* of the irregular polygon which is to be surveyed. They, therefore, divide up this polygon into triangles, whence this method of surveying is sometimes called "chain triangulation."

A few examples will make the principle and practice perfectly clear.

A Three-sided Field. Field Work.—Measure the three sides A B, B C, and C A. Measure also, as a proof-line, the distance from one of the corners, as C, to some point in the opposite side, as D, at which a mark should have been left when measuring from A to B, at a known distance from A. A stick or thing with a slit in its top to receive a piece of paper, with the distance from A marked on it, is the most convenient mark.

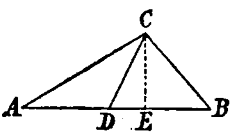


Fig. 22.

Platting.—Choose a suitable scale, then draw a line equal in length, on the chosen scale, to one of the sides; A B, for example. Take in the compasses the length of another side, as A C, to the same scale, and with one leg in A as a centre describe another arc, intersecting the first arc in a point which will be the third corner, C. Draw the lines A C and B C, and A B C will be the plat or miniature copy of the field surveyed.

Instead of describing to acres to get the point C, two pairs of compasses may be conveniently used. Open them to the lengths respectively of the last two sides. Put one foot of each at the ends of the first side, and bring their other feet together, and their point of meeting will mark the desired third point of the triangle.

To "prove" the accuracy of the work, fix the point D by setting off from A the proper distance, and measure the length of the line D C. If its length on the plat correspond to its measurement on the ground, the work is correct.

Calculation.—The content of the field may now be found, either from the three sides, or more easily though not so accurately by measuring on the plat the length of the perpendicular C E, let fall from any angle to the opposite side, and taking half the product of these two lines.

Example 1.—Fig. 22 in the plat, on a scale of 2 chains to an inch, of a field of which the side A B is 200 links, B C is 100 links, and A C is 150 links. Its content is 0·726 of a square chain, or 0 acres, 0 rods, 12 poles. If the perpendicular A D be accurately measured, it will be found to be 72½ links. Half the product of this perpendicular by the base will be found to give the same content.

Example 2.—The three sides of a triangular field are respectively 89·38, 54·09, and 45·98. Required its content. *Answer*, 100 acres 0 roods 10 poles.

The field notes of the triangular field plotted in

Fig. 49 are given below, according to both the methods mentioned in the preceding article.

In the field-notes in the column on the right hand it is not absolutely necessary to repeat the B and C.

Proof-line.	From D	89 F. S.	to C
Side.	From C	150 ⊙	to A ┐
Side.	From B	100	to C
Side.	From A	200 80 ⊙	to B F. S.

Proof-line.	From	C 89 (80)	on 200
Side.	┐	A 150 C	
Side.	┐	C 100 B	
Side.		B 200 (80) A	

A Four-sided Field. Field Work.—Measure the four sides. Measure also a diagonal as A C, thus dividing the four-sided field into two triangles. Measure also the other diagonal as a "proof-line."

Platting.—Draw a line, as A C, equal in length to the diagonal, to any scale; on each side of it construct

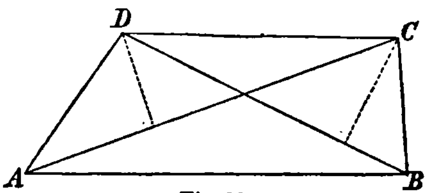


Fig. 23.

a triangle with the sides of the field, as directed in the preceding article.

To prove the accuracy of the work, measure on the plat the length of the "proof-lines," B D, and if it agrees with the length of the same line measured on the ground, the field work and platting are both proved to be correct.

Calculation.—Find the content of each triangle separately, as in the preceding case, and add them together; or, more briefly, multiply either diagonal (the large one is preferable) by the sum of the two perpendiculars, and divide the product by two. Otherwise, reduce the four-sided figure to one triangle, or use any of the methods of the preceding chapter.

Example 1.—In the field drawn in Fig. 23, on a scale of 3 chains to the inch, A B = 588 links, B C = 210 links, C D = 430, D A = 274, the diagonal A C = 626, and the proof diagonal B D = 500. The total content will be 1 acre 0 rods 17 poles.

Example 2.—The side of a four-sided field are A C = 12·41, B C = 5·86, C D = 8·25, D A = 4·24; the diagonal B L = 11·55, and the proof-line A C = 11·04. Required the content. *Ans.*, 4 acres 2 rods 38 poles.

A many-sided Field. Field Work.—Measure all the sides of the field. Measure also diagonals enough to divide the field into triangles, of which there will always be two less than the number of sides. Choose such diagonals as will divide the field into triangles as nearly equilateral as possible. Measure also one or more diagonals for "proof-lines."

Platting.—Begin with any diagonal and plat one triangle. Plat a second triangle adjoining the first one. Plat another adjacent triangle, and so proceed till all are laid down in their proper places. Measure the proof-lines as in the last article.

Calculation.—Proceed to calculate the content of the figure precisely as directed for the four-sided field, measuring the perpendiculars and calculating the content of each triangle in turn; or taking in pairs those on opposite sides of the same diagonal; or using some of the other methods which have been explained.

Example 1.—The six-sided field chosen in Fig. 24 has the length of its lines, in chains and links, written

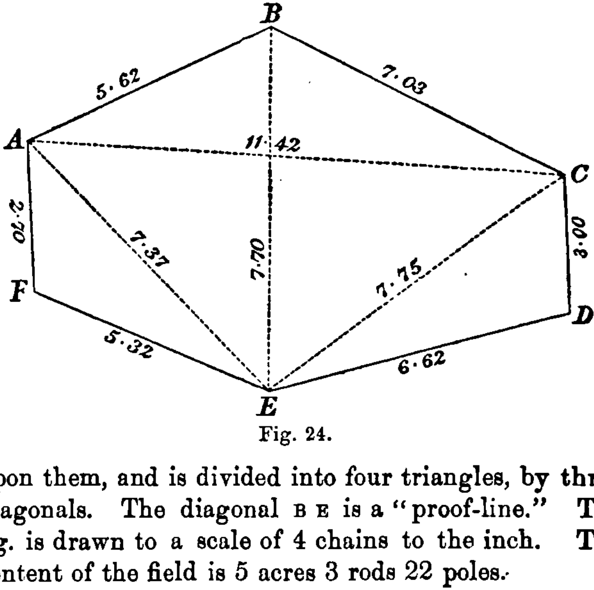


Fig. 24.

upon them, and is divided into four triangles, by three diagonals. The diagonal B E is a "proof-line." The fig. is drawn to a scale of 4 chains to the inch. The content of the field is 5 acres 3 rods 22 poles.

Example 2.—In a five-sided field the length of the sides are as follows: A D = 2·69
B C = 1·22
C D = 2·32
D E = 3·55
E A = 3·23

The diagonals are A D = 4·81
and . . . . . B D = 3·33 Required the content.

A field may be divided up into triangles, not only by measuring diagonals as in the last figure, but by any of the methods shown in the four figures. The one which we have been employing corresponds to the last of those figures.

Still another may be used when the angles cannot be seen from one another, or from any point within. Take three or more convenient points within the field, and measure from them to the corners, and thus form different sets of triangles.

The field-notes of the survey plotted in Fig. 24 are given below. They begin at the bottom of the left-hand column.

Side		F	
		532	
		300	Gate.
		E	
Side.		E	
		662	Brook.
		400	
		D	
Side.		D	
		300	
		270	Road.
		211	
		80	
		C	
Side.		C	
		703	
		150	Gate.
		B	
Side.		B	
		562	
		A	

Proof-line.		E	
		770	
		B	
Diagonal.		A	
		1142	
		C	
Diagonal.		C	
		775	
		480	Road.
		420	
		E	
Diagonal.		E	
		737	
		280	Road
		210	
		A	
Side.		A	
		270	
		130	Road.
		80	
		F	

Surveying by Tie-lines.—This is a modification of the method explained in the previous article. It frequently happens that it is impossible to measure the diagonals of a field of many sides, in consequence of obstacles to measurements, such as woods, water houses, &c. In such cases "tie-lines" (so called because they *tie* the sides together) are employed as substitutes for diagonals. Thus, in the four-sided field shown in the figure, the diagonals cannot be measured because of woods intervening. As a substitute, measure off from any convenient corner of the field, as B, any distance, B E, B F, along the sides of the field. Measure all the sides of the field as usual.

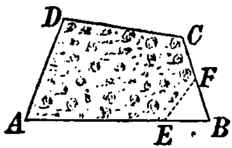


Fig. 25.

To plot this field, construct the triangle B E F, produce the sides B E and B F, till they become respectively equal to B A and B C, as measured on the ground. Then with A and C as centres, and with radii equal A D and C D, describe arcs whose intersection will be D, the remaining corner of the field.

It thus appears that one tie-line is sufficient to determine a four-sided field; two a five-sided field, and so on. But as a check on errors, it is better to measure a tie-line for each angle, and the agreement, in the plot, of all the measurements will prove the accuracy of the whole work.

The tie-lines should be as long as possible, as the nearer the corner the tie-line is drawn the more it magnifies inaccuracies in the side lines.

A tie-line may also be employed as a *proof-line* in the place of a diagonal, and tested in the same manner. If any angle of a field is re-entering, as at B, Fig. 26, measure a tie-line across the salient angle, A B C.

Chain Angles.—It is convenient, though not necessary, to measure equal distances along the sides; B E, B F, in Fig. 25, and B A, B C in Fig. 26. "Chain angles" are thus formed.

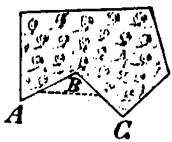


Fig. 26.

Inaccessible Areas.—The method of tie-lines can be applied to measuring fields which cannot be entered. Thus, in the fig., A B C D is an inaccessible wooded field of four sides. To survey it, measure all the sides, and at any corner, as D, measure any distance D E—the line D A produced. Measure also another distance, D F, in the line of C D produced. Measure the tie-line E F, and the figure can be platted as in the case of the field of Fig. 24, the sides of the triangle being produced in the contrary direction.

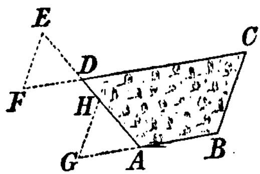


Fig. 27.

The same end would be obtained by prolonging only one side, as shown at the angle A of the same figure, and measuring A G, A H, and G H. It is better in both cases to tie all the angles in a similar manner.

This method may be applied to a figure of any number of sides by prolonging as many of them as are necessary, all of them if possible.

Surveying by Perpendiculars.—The method of surveying by perpendiculars is founded on the second method of determining the position of a point explained. It is applied in two ways, either to make a complete survey by "*Diagonals* and *Perpendiculars*," or to measuring a crooked boundary by "offsets." Each will be considered in turn.

The best methods of getting perpendiculars on the ground must, however, be first explained.

To set out Perpendiculars.

Surveyor's Cross.—The simplest instrument for this purpose is the *surveyor's cross* or cross-staff, shown in Fig. 3.

Optical Square.—The most convenient and accurate instrument for taking perpendiculars is, however, the *optical square,* Fig. 6.

Chain Perpendiculars.—Perpendiculars may be set out with the chain alone by a variety of methods, these methods generally consist in performing on the ground the operations executed on paper in practical geometry, the chain being used in place of the compasses to describe the necessary arcs.

These operations, however, are less often used for the method of surveying now to be explained than for overcoming obstacles to measurement.

Perpendiculars to any line are readily laid out with a chain, as carpenters and masons draw right angles by what they call the 6, 8, and 10 rule, the popular application of the principle of the square of the hypothenuse being equal to the sum of the squares of the other two sides. The method is to measure from the point where the perpendicular meets the line, either along the line or along the perpendicular, a distance equal to 6 units of any kind, and then upon the other of these lines a distance of 8 units. The two lines are perpendicular to each other when the two termini are just 10 units apart. Convenient distances for this measurement might be 3, 4, and 5 rods or chains, or any similar multiples of these numbers, as 21, 28, and 35. Other trigonometrical methods readily suggest themselves.

Diagonals and Perpendiculars.

We have seen that plats of surveys made with the *chain* alone have their contents most easily determined by measuring on the flat the perpendiculars of each of the triangles into which the diagonals measured on the ground have divided the field. In the method of *surveying by diagonals and perpendiculars*, now to be explained, the perpendiculars are *measured on the ground.* The content of the field can therefore be found at once (by adding together the half products of each perpendicular by the diagonal on which it is let fall), without the necessity of previously making a plat, or if necessary the sides of the field. This is, therefore, the most rapid and easy method of surveying *when the content alone is required,* and *is particularly applicable to the measurement of ground occupied by crops,* for the purpose of determining the number of bushels grown to the acre, the amount to be paid for mowing by the acre, &c.

A Three-sided Field.—Measure the longest side, A B, and the perpendicular, C D, let fall upon it from the opposite angle, C.

Then the content is equal to half the product of the side by the perpendicular.

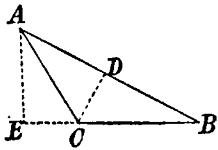


Fig. 28.

If obstacles prevent this, find the point where a perpendicular let fall from the angle, as A, to the opposite side produced, as B C, would meet it, as at E in the figure.

A Four-sided Field.—Measure the diagonal A C. Leave marks at the points on the diagonal at which perpen-

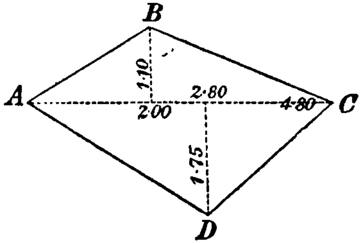


Fig. 29.

diculars from B and from D would meet it, finding these points by trial.

The best marks at these "false stations" have been described.

Example 1.—Required the content of the field, Fig. 29. *Answer*, 0 acres 2 rods 29 poles.

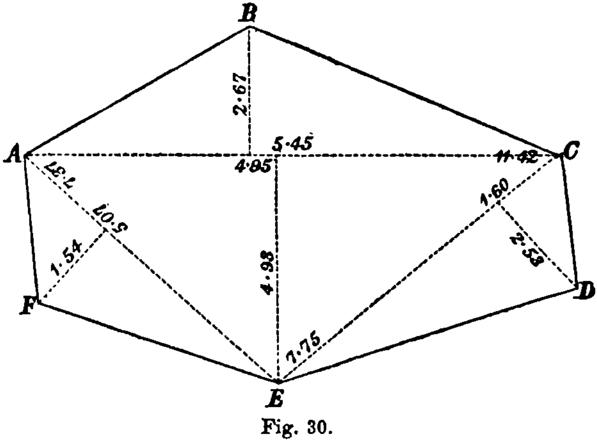


Fig. 30.

The field may be plotted from these measurements if desired, but with more liability to inaccuracy than in the *first method*, in which *the sides are measured.* The plat of the figure is 3 chains to an inch.

Example 2.—Calculation :—(Fig. 29.)

	Sq. Links.
A B C = $\frac{1}{2} \times 480 \times 110$ =	26400
A D C = $\frac{1}{2} \times 480 \times 175$ =	42000
Sq. Chains . .	6·8400
Acres	0·684

It is still easier to take the two triangles together, multiplying the diagonal by the sum of the perpendicular and dividing by 2.

A Many-sided Field.—Fig. 30 and the accompanying field notes represent the field which was surveyed by the *first* method and plotted in Fig. 24.

	54	to F.
From 5·07 on 7·37 .	F. S.	
	2·53	to D.
From 1·60 on 7·75 .	F. S.	
	4·93	to E.
From 5·45 on 11·42 .	F. S	
	2·67	to B.
From 4·95 on 11·42 .	F. S.	
	7·37	to A.
F. S.	5·07	
From E.	⊙	ſ
	7·75	to E.
F. S.	1·60	
From C.	⊙	ſ
	11·42	
	5·45	F. S.
F. S.	4·95	
From A.	⊙	

Example 1. *Calculations.*—The content of the triangles may be expressed thus:—

								Sq. Links.
A B C	=	$\frac{1}{2}$	×	1142	×	267	=	152457
A E C	=	$\frac{1}{2}$	×	1142	×	493	=	281503
C D E	=	$\frac{1}{2}$	×	775	×	253	=	98037
A E F	=	$\frac{1}{2}$	×	737	×	154	=	56749
				Sq. Chains . .				58·8746
				Acres				5·88746

The first two triangles might have been taken together, as in the previous field.

Content calculated from the perpendiculars will generally vary slightly from that obtained by measuring on the plat.

Offsets are short perpendiculars, measured from a straight line to the angle of a crooked or zigzag line

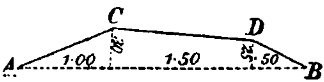
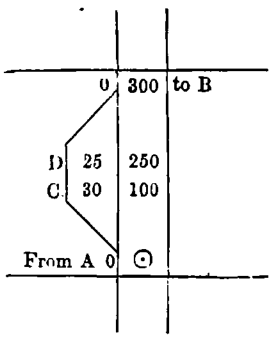


Fig. 31.

near which the straight line runs. Thus, let A B C D be a crooked fence bounding one side of a field. Chain



along the straight line A B, which runs from one end of the fence to the other, and when opposite each corner note the distance from the beginning, or the point A, and also measure and note the perpendicular distance of each corner, C and D, from the line.

A more extended example, with a little different notation, is given in Fig. 32.

	B	
	1500	0
	1250	20
0	1000	0
30	750	
50	500	
40	250	
	0	
	A	

Fig. 32.

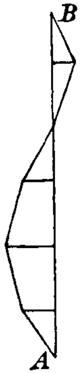


Fig. 32.

In the figure, which is on a scale of 8 chains to an inch for the distance along the line, the breadth of the offsets are exaggerated to four times their true proportional dimensions.

The offsets may generally be taken with sufficient accuracy by measuring them as nearly as possible at right angles to the base line as the eye can estimate.

They may be measured, if short, with an offset-staff, a light rod 10 or 15 links in length, and divided accordingly; or, if they be long, with a tape. They are generally but a few links in length. A chain's length should be the extreme limit. When the cross-staff is in use, its divided length of 8 links renders the offset-staff needless.

The offsets are to be taken to every angle of the piece or other crooked line; that is, to every point where it changes its direction.

Platting.—The most rapid method of platting the offsets is by the use of a *platting scale* and an *offset scale*, which is a short scale divided on its edges like a platting scale, but having its zero in the middle, as in Fig. 33.

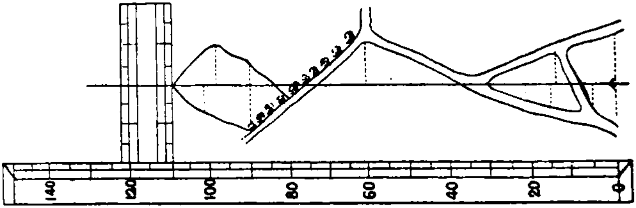


Fig. 33.

The platting scale is placed parallel to the line, with its zero point opposite the beginning of the line. The offset scale is slid along the platting scale till its edge comes to a distance on the latter at which an offset had been taken, the length of which is marked off with a needle point from the offset scale. This is then slid on to the next distance, and the operation is repeated. If one person reads off the field notes and another plats, the operation will be greatly facilitated. The points thus obtained are joined by straight lines, and a miniature copy of the curved line is thus obtained, all the operations of the platting being merely repetitions of the measurements made on the ground.

Calculating Content.—When the crooked line determined by offsets is the boundary of a field, the content enclosed between it and the straight line surveyed must be determined, that it may be added to or subtracted from the content of the field bounded by straight lines. There are various methods of effecting this.

The area enclosed between the straight lines and the crooked lines is divided up by the offsets into *triangles* and *trapezoids*, the content of which may be calculated separately and then added together. *Example* 1. The content of Fig. 32 will therefore be 1500 + 4125 + = 6250 square links = 0·625 square chains. *Example* 2. The content of plat, Fig. 32, will in like manner be found to be on the left of the straight line 30·000 square links, and on its right 5·000 square links.

When the offsets have been taken at equal distances, the content may be more easily obtained by adding together half of the first and of the last offset, and all the intermediate ones, and multiplying the sum by one of the equal distances between the offsets. This rule is merely an abbreviation of the preceding one.

Thus, in Fig. 32 the distances being equal, the content of the offset on the left of the straight line will be 120 × 250 = 30,000 square links, and on the right side 20 × 250 = 5,000 square links—the same result as before.

When the line determined by the offsets is a curved line, "Simpson's Rule" gives the content more accurately. To employ it, an *even* number of *equal* distances must have been measured in the part to be calculated; then add together the *first* and *last* offsets, four times the sum of the *even* offsets (*i.e.* the 2nd, 4th, 6th, &c.), *twice* the *sum* of the odd offsets (*i.e.* the 3rd, 5th, 7th, &c.), *not* including the first and last. Multiply the sum by one of the equal distances between the offsets and divide by 3. The quotient will be the area.

Example 1. The offsets from a straight line to a curved fence were 8, 9, 11, 15, 16, 14, 9 links, at equal distances of 5 links. What was the content included between the curved fence and the straight line? *Answer*, 371·666.

Many *erroneous rules* for calculating offsets have been given, such as—(*a*). To divide the sum of all the offsets by one less than their number, and multiply the quotient by the whole length of the straight line; or what is the same thing, to multiply the sum of all the offsets by the common distance between them.

(*b*). To divide the sum of all the offsets by their number, and then to multiply the quotient by the straight line.

Reducing to one triangle the many-sided figures which are formed by the offsets is the method of calculation sometimes adopted.

Equalizing, or *giving* and *taking*, is an approximate mode of calculation much used by practical surveyors. A crooked line, determined by offsets, having been platted, a straight line is drawn on the plat across the crooked line, leaving as much space outside of the

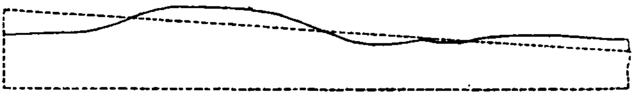


Fig. 34.

crooked line as inside of it, as nearly as can be estimated by the eye, *equalizing* it, or *giving* and *taking* equal portions. The straight line is best determined by laying across the irregular outline the straight edge of a piece of transparent horn, or tracing-paper, or glass, or a fine thread or horsehair. In practical hands this method is sufficiently accurate in most cases.

Surveying by Diagonals, Tie-lines, and Perpendiculars combined.

All the above methods of surveying, and that of perpendiculars particularly, in the form of offsets, are frequently required in the same survey.

The method of *diagonals* should be the leading one. In some parts of the survey obstacles to the measurement of diagonals may require the use of *tie-lines*, and if the fences are crooked, straight lines are to be measured near them, and their crooks determined by *offsets*.

Offsets are necessary additions to almost every other method of surveying. In the smallest field surveyed by diagonals, unless all the fences are perfectly straight lines, their bends must be determined by offsets. The plot (scale 1 chain to an inch) and field notes of such a case are given below. A sufficient number of the sides, diagonals, and proof-lines, to prove the work, should be plotted before plotting the offsets.

Side.		C	
	0	360	
	6	315	
	10	275	
	5	215	
	0	150	0
		115	10
		80	5
		65	8
		B	0 Γ

Side.		B	
	0	125	
	11	90	
	23	62	
	12	22	
	0	A	

Proof-Line.		B	
		340	
		D	

Diagonal.		C	
		310	
		A	Γ

Side.		A	
	0	248	
	11	180	
	0	105	0
		65	5
		D	0 Γ

Side.		D	
	0	135	
	15	110	
	13	90	
	0	50	0
		30	9
		C	0 Γ

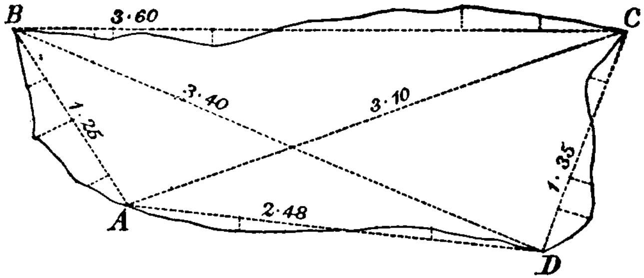


Fig. 35.

Inaccessible Areas.—A combination of *offsets* and *tie-lines* supplies an easy method of surveying an inaccessible area, such as a pond, swamp, forest, block of houses, &c., as appears from the Fig. 36, in which the

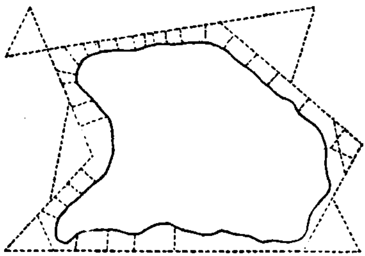


Fig. 36.

external boundary lines are taken at will and measured, and tied by the "tie-lines" measured between those lines, prolonged when necessary, while offsets from them determine the irregularities of the actual boundaries of the pond, &c.

These offsets or insets and their content is, of course, to be subtracted from the content of the principal figure.

Even a circular field might thus be approximately measured from the outside.

A great variety of expedients are adopted for overcoming natural obstacles and determining the extent and shape of inaccessible objects, systems of triangles being in such cases formed outside of and around such objects.

In surveying buildings and enclosures which cannot be passed through, it is done by means of rectangles, as shown in Fig. 37.

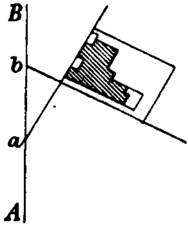


Fig. 37.

CHAPTER VII.

SURVEYING WITH THE THEODOLITE.

A MORE common system of surveying (than with the chain alone) is that in which instruments for taking angles are employed in connection with the chain. A graduated horizontal circle, with a straight edge called an alidade turning upon its central point, which may be conveniently sighted along, furnishes the means of ascertaining the regular distances of two lines, the instruments being set at their intersection, and the alidade pointed in the direction of one and then of the other. This involves the principle of the engineering *transit* or of the *theodolite.*

With these instruments angles can be determined with great accuracy, especially when the observations are repeated by reversing the instrument and taking the mean, each including the reading of both verniers.

A tract of almost any dimensions is accurately surveyed by measuring the angles at its corners, or the correction of the work is proved when the product of all the interior angles is found equal to the product of two right angles, or 180°, by the number of sides of the tract less two; or if the instruments be used by the method called *traversing,** "or surveying by the back

* *Traversing* is a combination of linear and angular measurement.

angle" (which consists in noting the angle which each successive line makes, not with the preceding line, but with the first line observed, which is hence called the meridian of the survey), then the reading, on getting round to the last station, and looking back to the first line, should be 360° or 0°.

Transit Theodolite.—The transit theodolite is the most perfect instrument used in surveying, and measures at the same time both the horizontal angles between two objects observed with it, and the angles of elevation of these points from the point of observation.

Fig 39 represents Stanley's 5-inch transit theodoite, with p ure achromatic telescope, erect and invert-

Traversing surveys are made by measuring the lengths of the bases and the angles they make with each other.

As checks:—

(1.) The exterior angles of the polygon should amount to 360°.*

(2.) Fix a point near the centre and divide the polygon into triangles, and measure the angles this point makes with the base lines.

(3.) By prolonging two adjacent sides so as to form one large triangle, and measuring the angles B, C, D, and E, and also P and Q if desired.

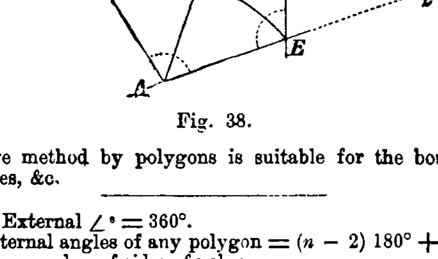


Fig. 38.

The above method by polygons is suitable for the boundaries of, fields, estates, &c.

* Σ External $\angle^s = 360°$.
Internal angles of any polygon $= (n - 2)\ 180° + x$.
$n =$ number of sides of polygon.
x calculated from area of figure.

ing eye-pieces, vertical and horizontal circles divided in silver to 30′, two verniers and two microscopes to each circle, clamping and tangent screw motions, mounted on a mahogany tripod stand.

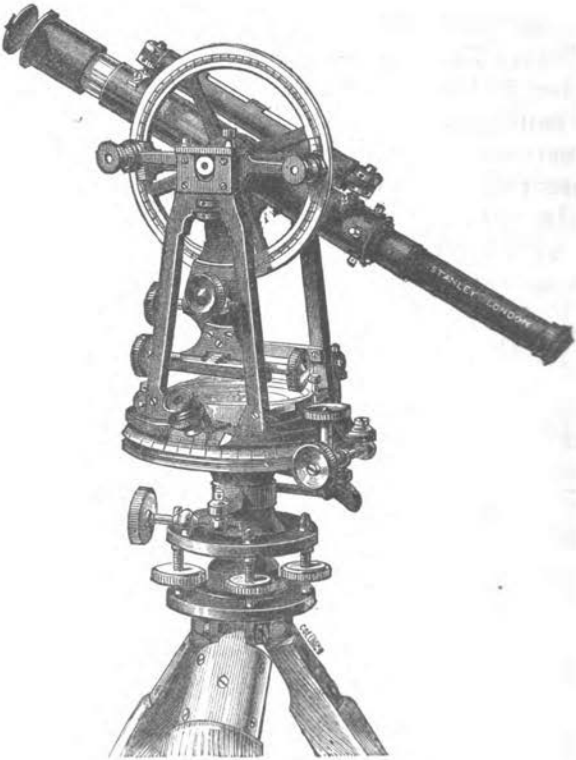


Fig. 39.

On the vernier of some theodolites are three indices at angles of 120°, instead of two indices at 180°. Two indices correct for eccentricity; three indices correct for eccentricity and ellipticity.

Theodolite Adjustments.—The adjustments for the theodolite are :—

Temporary—

(1.) Vertical axis at ⊙.

(2.) Level the instrument, or place vertical axis truly vertical ; and

(3.) Adjust the prevent parallax, or bring the foci of the glasses to the cross-wires.

The first and second adjustments require to be made every time the instrument is set up ; the third may require to be made at every observation.

Permanent—

(1.) Adjust the line of collimation.

(2.) Adjust the level.

(3.) Ascertain index-error of vertical circle ; and

(4.) Adjust horizontal axis exactly perpendicular to vertical axis.

Prismatic Compass.—A compass may be employed in filling up the interior details of a large survey with the transit.

Surveying by the compass is done by taking the bearings of the measured bases from the magnetic meridian. The magnetic needle, wherever the instrument is set, establishes the meridian line, and from this, the sights of the instrument having been turned to any other line, the angle of divergence is read on the graduated circle around the compass box. It is rapid, but not accurate ; but it may be depended upon as safe from great errors, such as 10° or any whole number.

Fig. 40.

The instrument, as in Fig. 40, is usually furnished with sights for the more accurate noting of the angles.

Box-Sextant.—A box-sextant will be found a more valuable auxiliary in filling up the details of a survey.

To save time in surveying, angles should be measured directly with the sextant. This is done by means of a level table upon which the sextant is laid; and poles are used, or a plumb line, &c., to enable the observer to bring the line of sight of the objects to the same horizontal plane.

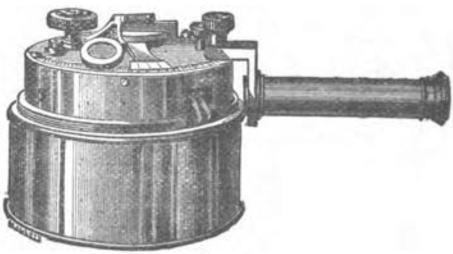


Fig. 41.

One of Stanley's box-sextants, divided in silver, with telescope and supplementary arc, is shown in Fig. 41.

Adjustments—

(1.) Index glass	.	Index glass ⊥ to plane of instrument.
(2.) Horizon glass	.	Horizon glass ⊥ to plane of instrument.
(3.) Index error	.	Ascertain the index error.
(4.) Collimation	.	Line of collimation of telescope ∥ to plane of instrument.

Correction for "index error" in adjusting the sextant may be necessary for two causes, but it is generally only the first of these that requires attention, the cause of the second happening very rarely in surveys with such instruments.

(1.) Deviation of the index from its correct position.

(2.) The object looked at may be so near the observer that the rays coming from it may not be sensibly parallel, as they would be at a distance.

TABLE FOR ASCERTAINING HEIGHTS AND DISTANCES BY THE BOX-SEXTANT.

Mul.	Angle.	Angle.	Div.
	Degs.	Degs.	
1	45·00	45·00	1
2	63·26	26·34	2
3	71·34	18·26	3
4	75·58	14·02	4
5	78·41	11·19	5
6	80·32	9·28	6
8	82·52	7·08	8
10	84·17	5·43	10

In land measuring on a large scale, a theodolite is invariably used for the measurement of angles. A base line is first chosen and carefully measured, and from each extremity, which is marked by some object visible from a considerable distance, the angle between the other extremity and an arbitrarily chosen and convenient point is measured. This may be done directly, or, as is more usual, the geographical bearings of the new point with respect to the other points are measured, the orientation of the base line itself being already known. Thus the base and contiguous angles of the triangle are given, and from these the other sides and area can be easily calculated. Each of the sides is now taken as a new base line, and new triangles are constructed upon them by arbitrarily choosing new vertices; and thus, by the simple observation of the necessary angles and the careful measurement of one base line, a large tract of country is triangulated or surveyed.

To tell the accuracy of the observations and to fix the limits of error, the last side, whose calculated value depends upon *all* the observations leading up to it, is measured directly as the original base line was.

When the triangulation extends over a whole country, corrections must be applied to the value calculated, because of the sphericity of the earth. The triangles are not plain but spherical, and the problem is therefore really one of spherical trigonometry.

The *details of surveys* are necessarily modified according to the extent of the area, character of the ground, &c. With the transit or compass, the bounding lines may be all followed out, and the angles they make with each other determined and their lengths measured by the chain; the points of crossing of roads, brooks, fences, &c., measured, and the bearings of these objects taken; and increased accuracy may be given to the work by measuring *diagonal or proof-lines*, as in chain surveying.

Additional checks are furnished by taking at each station the bearings of square-marked objects, which, when the work is plotted, should severally fall at the point of intersection of the lines directed toward these objects from the several stations.

Sometimes a tract may be surveyed from a measured base line, either a line within or without it, or one of the boundary lines, by placing the compass successively at each end of this line and taking the bearings of each corner; or, without a compass, the work may be very conveniently performed with appropriate correctness by plane *table method,* provided no angles are taken less than 30° nor larger than 150°.

A drawing-board covered with paper is set up at one end of a measured base line, and a ruler furnished with upright sights at each end, exactly over the drawing edge, is set with this edge against a fine needle stuck up in the board, and is then directed successively towards the covers of the tract to be surveyed and any other prominent objects, towards which from the needle lines are to be drawn on the paper. One of these lines should be in the direction of the measured line.

The instrument is then taken to the other end of the measured line, the needle is removed along the last line named on the board a distance corresponding, according to the scale adopted, to that of the measured line on the ground, and the board is so placed as to make the line toward the former station.

The ruler is then again pointed to the same object, and lines are drawn toward each from the new position of the needle. Their intersection with the former lines designate the places of these objects on the plane.

The *plane* table is used in various other ways, as by moving it from one corner to the next, and placing it at each so that the last line drawn coincides with that in the ground. From any central point also radiating may be measured to the corners, and the distances measured and marked off to the proper scale.

Rivers, brooks, and roads are surveyed by measuring a succession of lines following their several courses, and taking offsets from the sides of the line.

Protractor.—To accompany the theodolite, &c., there must be provided a protractor, to plot the angles that are taken by the instrument.

The circular protractor with vernier and arm, as in Fig. 42, is the one now commonly used.

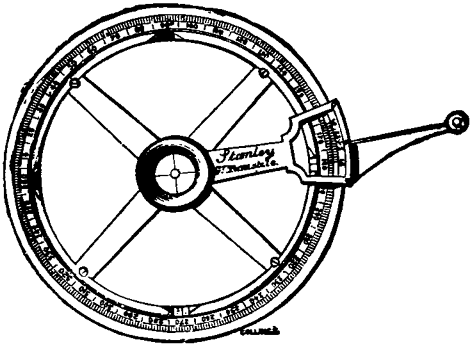


Fig. 42.

To Measure an Angle by the Protractor.—From the centre of the protractor at the point or angle A, and the edge along the line A B, extend the lines sufficiently

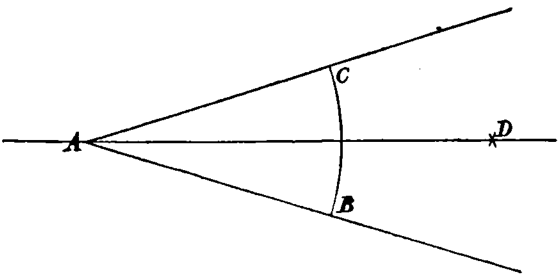


Fig. 43.

to read where it cuts the outer edge of the protractor, and the number of degrees and minutes it reads from B to C will be the measure of the angle required.

CHAPTER VIII.

LEVELLING.

Levelling is the art of determining the difference of the heights of two or more points, or of finding the comparative heights of different points of the earth's surface. It is that branch of geodesy which treats of the measurement of heights either (1) *absolute,* when referring to the sea level, or (2) *relative,* between any two distant places on the earth's surface.

Methods.—There are three principal and independent methods in use.

The *first* and most accurate method—that of direct levelling—employs the levelling instrument, and depends on the property of fluids when at rest to present their surfaces at right angles to the direction of gravity.

The *second,* or trigonometrical method, employs the theodolite, and depends on the angular measure of elevation, in combination with the known distance of the object, and having regard to the effect of atmospheric refraction. This is the only method applicable in case one or both stations are inaccessible.

The *third* or barometric method depends on the law of the decrease of pressure of the atmosphere with an increase of altitude. It is the least accurate method of the three, and is of no value for determining small differences of level at any two or more points, though very serviceable in ascertaining approximately the altitude of a station, mountain, &c., above sea-level.

Level Lines and Surfaces.—A *level surface* is one that is concentric with the surface of the ocean; that is, with the surface the ocean would have if the globe were entirely covered with water.

Any line drawn on a level surface is a *level line.*

A surface of *apparent level* at any point is a plane drawn tangent to the surface of true level at that point. Any line drawn on a surface of apparent level is a line of apparent level.

The lines indicated by our levelling instruments are *lines of apparent level,* but we may deduce from them lines of *true level* by making suitable corrections for curvature and refraction. With short distances, however, such corrections are unnecessary.

Curvature.—The level line given by an instrument is tangent to the surface of the earth. Therefore the line of true level is always the line of apparent level. In Fig. 44, A B represents the line of apparent level, and A C the line of true level. B C is the correction for the earth's curvature.

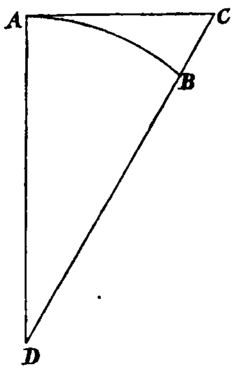


Fig. 44.

$AB^2 = BC \times (BC + 2CD)$. But BC being very small compared with the diameter of the earth, may be dropped from the quantity in the parenthesis, and we have—

$$BC = \frac{AB^2}{2CD}$$

that is, the correction equals the square of the distance divided by the diameter of the earth.

The difference of height for a distance of

$$1 \text{ mile} = \frac{1}{7916} = \frac{5280 \times 12}{7916} = 8 \text{ inches.}$$

This varies as the square of the distance. The effect, if neglected, is to make distant objects appear lower than they really are.

The effect is destroyed by setting the instrument mid-way between the two points.

Refraction.—Rays of light coming through the air are curved downwards. The effect is to make objects look higher than they really are. It amounts to about one-seventh that of curvature, and it operates in a contrary direction.

Correction.—Correction for curvature is, therefore, always to be subtracted—

$$= \frac{x^2}{2R} \qquad \begin{array}{l} x = \text{distance in feet.} \\ R \text{ earth's radius.} \end{array}$$

Refraction is to be added—

$$= \frac{x^2}{12R}$$

Curvature and refraction combined is to be subtractel from staff-readings—

$$= \text{on an average } \frac{5}{6} \cdot \frac{d^2}{2R} = \frac{5}{6} \cdot \frac{\text{distance}'^2}{41{,}778{,}000'}.$$

Levelling Instruments.—The instruments used in levelling are of two classes. Those of the first class are used to point out or indicate a line or surface of apparent level, and are technically termed *levels;* those of the second class are used to measure the distances of this line or surface of apparent level above the points whose difference of level is to be determined, and these are called *levelling rods.*

Levels.—These are constructed on one of three principles—

(1.) A line of apparent level is perpendicular to a plumb line freely suspended.

(2.) A line of apparent level is tangent to the free surfaceof a liquid in equilibrium; and

(3.) A ray of light which is perpendicular to a vertical mirror is a line of apparent level.

(1.) The levels used by bricklayers, carpenters, &c., afford an example of the method of applying the first principle. In its simplest form, this kind of level consists of a T-shaped frame, the line corresponding to the top of the T being perfectly straight and at right angles to a second line drawn through the middle of the stem of the T. A plumb-line is attached to some point of the second line, and when the instrument is held so that the plumb-line corresponds to this second line, the first line is a line of apparent level. The cross line of the T may be turned downwards, as is usually the case when used by mechanics, or it may be turned upwards, in which case, if supported on a suitable stand, it can be used for the rougher kinds of field levelling.

(2.) The ordinary Dumpy level (Fig. 45) affords an illustration of the second principle. It consists essentially of a telescope mounted on a tripod stand. The tripod itself is attached to a solid bar called the limb, which turns about an axis at right angles to it, and so arranged that the axis may be made vertical by the aid of levelling screws. Attached to the telescope is a ring compass and a delicate spirit-level. The latter, when in adjustment, is parallel to the line of collimation of the telescope, which is indicated by two cross hairs mounted on an adjustable diaphragm placed in the common focus of the field lens and eye-piece.

The parts of the instrument are so constructed that they may be brought into accurate adjustment—that is, with proper relative positions. When the instrument

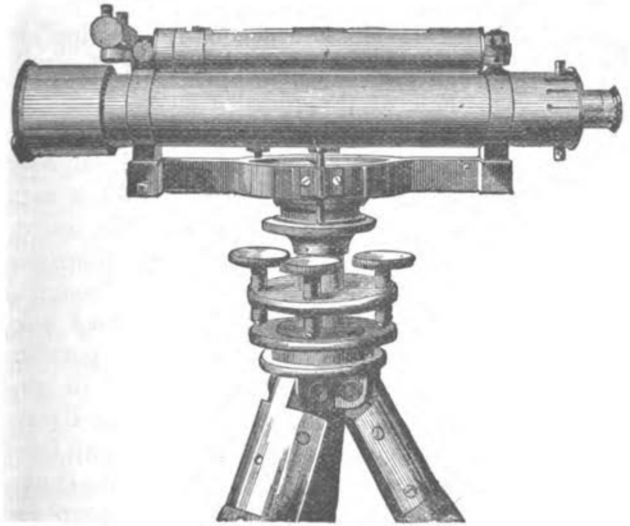


Fig. 45.

is adjusted, the attached level is parallel to the line of collimation of the telescope, and both are perpendicular to the axis of the limb, that is, the line that remains fixed when the limb is turned in *azimuth*.

The necessary adjustments of level are—

Temporary.—(1.) Level; (2.) Correct parallax.

Permanent.—(1.) Line of collimation || spirit level; (2.) Traverse.

To use the instrument thus adjusted we plant the tripod firmly in the ground, and by means of the levelling screws bring the level in such a position that the bubble will remain in the middle of the tube during an entire revolution in *azimuth*. The axis of the limb is then vertical, and consequently the line of collimation of the telescope in all its positions is a line of apparent level.

(3.) Levels constructed on the third principle are called *reflecting levels.* One form of this class of levels consists of a plate of glass suspended from a ring and weighted so that the plane of the glass shall always be vertical. One-half of the glass is silvered and the other half unsilvered, the line of division between the two portions being vertical. A line is ruled across the middle of the plate, perpendicular to the one last mentioned, and is consequently horizontal. To use the instrument, it is held by the ring, and raised or lowered until the observer sees the image of his eye reflected from the ruled horizontal line on the silvered portion; the plane through the eye in that position, and the line of the unsilvered portion, is a plane of apparent level. Instruments of this kind are convenient for contouring in topographical surveys, but they are not very accurate.

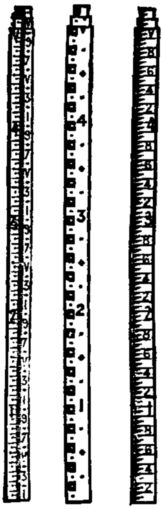


Fig. 46.

Levelling Rods.—These are rods of wood graduated to feet and decimals of a foot, the lines of division being numbered from below upwards; the 0 of the scale is at the bottom of the rod.

The one mostly used consists of a staff of hard wood in three slides or sections, and has the end capped with metal. It is made in length varying from 10 or 14 to 18 feet. The rod may be graduated in different ways; three patterns are shown in Fig. 46. A is a pattern of Sopwith's levelling rod; B is Rogers's field-pattern; and C is the Stanley pattern.

Another form of rod is now much used. It consists of a simple rod without a sliding vane, the divisions and numbers being so distinct as to make them easily read.

In levelling, the rod requires to be held at changes of slope, streams, banks, lines of communication, bench marks, &c.

A plummet is not necessary to set the staff perpendicular, for if the staff be moved backwards and forward, the true reading will be the smallest.

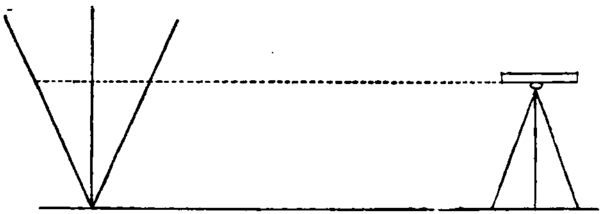


Fig. 47.

Sights.—A pair of sights, or readings, are required to make one complete observation. The first is called the back sight, and the second the fore sight.

The names back sight (B.S.) and Fore Sight (F.S.) do not necessarily mean sights taken looking backwards or forward, though they generally are so for turning points, but the first sight taken after setting up the instrument is a B.S. or + (plus) sight, and all following ones, taken before removing the instrument, are F.S., or — (minus) sights.

All but the first and last points sighted are called *intermediate points*, or "intermediates." The last point sighted to before moving the instrument is called a "turning point" or *changing point.*

Levels may be marked on the ground along a line of road or railway, &c., at distances of from 66 to 300 ft.

The principal reasons for taking sights at short distances is the uncertainty of the refracting action of the air. They should not be more than 10 chains, or 660 feet.

The only reason for a long sight is when great accuracy is not needed; then we may take the distances as far as we can read the staff, and reduce for curvature and refraction.

Most errors of observation increase as the distance simply.

Errors of refraction increase as the square of the distance merely.

But there are always errors which are constant, and do not vary with the distance.

The greater the distance the greater the effect, and therefore the more need that the instrument be planted exactly half way between fore and back sights.

Direct Levelling.—The levelling instrument is set up mid-way between any two consecutive stations, A and B, on the line of levels, and after its adjustment the

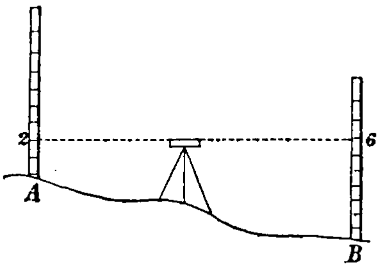


Fig. 48.

readings of the staves placed over the stations are necessarily taken. The line of sight having been made horizontal, the difference in the readings equals the difference of level of the two points A and B. (Fig. 48.)

When the first is subtracted from the second, if the remainder is +, the second point is higher than the first; if the remainder is — the second point is lower than the first.

In the same manner we may determine the difference in level between the second point and a third point, between the third and a fourth point, and so on, as far as may be desirable.

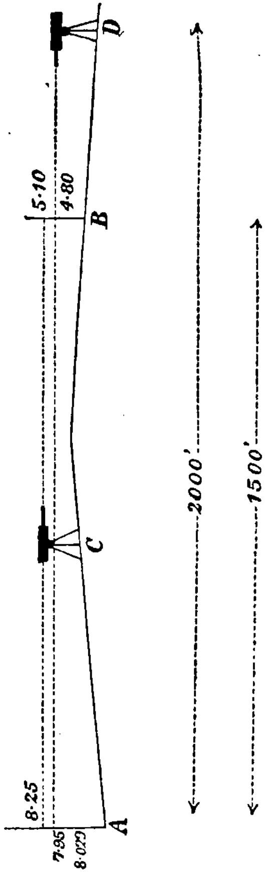


Fig. 49.

The total difference of level between the first point and the last is then equal to the algebraic sum of all the partial differences of level.

Example.—A levelling instrument was placed at a station C, mid-way between two bench marks, A and B. (Fig. 48).

Staff-reading at A . 8·25
Ditto at B . 5·10

The instrument was then shifted to a station D, near to B, and 2,000 feet from A.

Staff-reading at B . 4·80

Calculate—

(1.) True difference of level of A and B.

(2.) Error from curvature and refraction of reading at A as seen from D.

(3.) Proper staff-reading at A (including curvature and refraction).

(1.) The instrument being mid-way between A and B, the errors from curvature and refraction are neutralised, and the true difference of level of the two bench marks is the difference of their readings on the staff.

$$= 8{\cdot}25 - 5{\cdot}10 = 3{\cdot}15 \text{ feet.}$$

(2.) The error from curvature and refraction of reading at A as seen from D—

$$= \frac{5}{6} \times \frac{2000^2}{41{,}778{,}000} = \frac{5}{6} \times \frac{4{,}000{,}000}{41{,}778{,}000}$$

$$= \frac{5}{6} \times {\cdot}09574 = 0{\cdot}07978 \text{ feet.}$$

(3.) Proper staff-reading at A as seen from D, including effects of curvature and refraction.

$$= (4{\cdot}80 + 3{\cdot}15) + {\cdot}07978.$$
$$= 7{\cdot}95 + {\cdot}07978 = 8{\cdot}02978 \text{ feet.}$$

Note Regarding Adjustment of Level.

Let the readings from C be 8·25 at A and 5·10 at B. The difference of level is 3·15.

If the level is shifted to D, 2,000 feet from A and 500 feet from B, and reads 4·80 at B, then it would read 7·95 at A, if there was no error from curvature and refraction; but the error in 2,000 feet = ·079 ∴ the real reading at A from D should be 8·029. Now if the reading at A from D does not = 8·029, the line of collimation is out of adjustment. Suppose that what we do read is 7·53, or ·50 less than it should read, then ·50 represents the error in A B for 4·80 + 3·15 + ·079 = 8·029 = 7·53 + ·5.

The total error of adjustment in A D

$$= \text{error in A B} \times \left(\frac{\text{A D}}{\text{A B}} = \frac{2000}{1500} = \frac{4}{3}\right) = {\cdot}5 \times \frac{4}{3} = {\cdot}67.$$

Hence 7·53 + ·67 = 8·20 = the true reading at A; and 8·20 — 3·15 = 5·05 = true reading at B from D. Hence 5·05 — 4·80 = ·25 = error in B D.

The curvature and refraction in B D supposed to be inappreciable.

Field Notes.—Gillespie recommends the beginner to sketch the heights and distances measured in a profile or side view, as in Fig. 50. But when the observations are numerous they should be placed in one of the following tabular forms. These all refer to Fig. 50, and may be compared with that sketch.

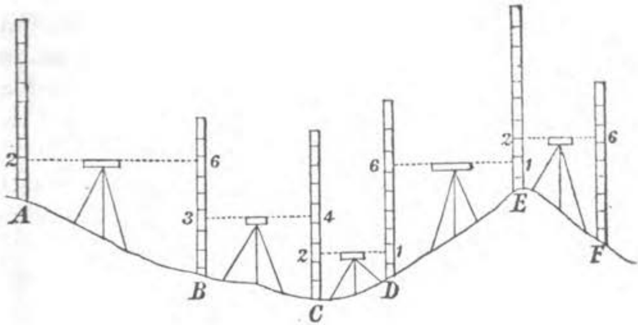


Fig. 50.

First form of Field Book.—In this the names of the points or "stations" whose heights are demanded are placed in the first column, and their height is finally

Stations.	Distances.	Back sights.	Fore sights.	Rise.	Fall.	Reduced Levels.	Remarks.
A						0·00	B.M., mark cut on wall of shepherd's cottage.
B	100	2·00	6·00		−4·00	−4·00	
C	60	3·00	4·00		−1·00	−5·00	
D	40	2·00	1·00	+1·00		−4·00	
E	70	6·00	1·00	+5·00		+1·00	
F	50	2·00	6·00		−4·00	−3·00	B. M., lower hook of gate of farmyard.
		15·00	18·00		−9·00		
					+6·00		
					−3·00		

ascertained in reference to the seventh column. The heights above the starting point are marked +, and those below it are marked —. The back sight to any station is placed on the line below the point to which it refers. When a back sight exceeds a fore sight, their difference is placed in the column of "rise"; when it is less their difference is a "fall."

The above table shows that B is 4 ft. below A, that C is 5 ft. below A, that E is 1 ft. above A, and so on. To test the calculation, add up the back sights and fore sight. The difference of the same should equal the last total height or reduced level.

Second form of Field Book.—This is presented below. It refers to the same stations and levels noted in the first table, and shown in Fig. 50.

Stations.	Distances.	Back sights.	Height of Inst. above Datum.	Fore sights.	Reduced Levels.	Remarks.
A					0·00	B.M.
B	100	2·00	+ 2·00	6·00	— 4·00	
C	60	3·00	— 1·00	4·00	— 5·00	
D	40	2·00	— 3·00	1·00	— 4·00	
E	70	6 00	+ 2·00	1·00	+ 1·00	
F	50	2·00	+ 3·00	6·00	— 3·00	B.M.
		15·00		18·00	— 3·00	

In the above table it will be seen that a new column is introduced, containing the heights of the instrument above the datum or starting-point. The former columns of "rise" and "fall" are omitted. The above notes are taken thus: The height of the starting-point, or "datum," at A is 0·00. The instrument being set up and levelled, the rod is held at A. The back sight upon it is 2·00; therefore the height of the instrument is also 2·00. The rod is next held at B. The fore sight to it is 6·00. That point is therefore 6·00 below the instrument, or 2 00 — 6·00 = — 4·00 below datum. The instrument is now moved, and again set up, and the back sight to B, being 3·00, the height of instrument 5 — 4·00 + 3·00 = 1·00, and so on, the height of instrument being always obtained by adding the backsight to the height of the peg on which the rod is held, and the height of the next peg being obtained by substracting the fore sight to the rod held on that peg from the height of instrument.

Third form of Field Book. —In this form the defects of the preceding methods are avoided, and it approximates to a sketch of the operations, the fore-sight being

F. S. −	Distances.	Stations.	Height of Staff.	B. S. +	Height of Inst.	Remarks.
		A	0·00	2·00	+ 2·00	B. M.
6·00	100	B	− 4·00	3·00	− 1·00	
4·00	60	C	− 5·00	2·00	− 3·00	
1·00	40	D	− 4·00	6·00	+ 2·00	
1·00	70	E	+ 1·00	2·00	+ 3·00	
6·00	50	F	− 3·00			B. M.
−18·00				+15·00		
				− 18·00		
				− 3·00		

placed before the stations to which they are taken, and the back sights after them. The distances are placed before the stations to which they are taken, or after those from which they are taken. Another advantage is that the stations, their heights, and the distances, are brought together, which facilitates the making of a profile.

In checking the level book after taking levels, the difference between the sums of back and fore sights should equal the difference of the sums of the rises and falls, and each of those quantities should be equal to the difference between the first and last numbers in the columns of reduced levels or height of staff.

Check Levels.—No single set of levels is to be trusted, but they must be tested by another set, run between the bench marks, though not necessarily over the same ground. A set of levels will verify themselves if they come around to the starting-point again. Check levels should be taken of bench marks, of lines of communication, of summits, and of hollows, and for working sections every level should be checked.

Trial Levels.—Their object is to get a general approximate idea of the comparative heights of a portion of the country, as a guide in choosing lines to be levelled more accurately, or for ascertaining the elevation of detached points of primary importance as regards the work in hand. More rapidity and less precision is required in these trial or flying levels.

Levelling Location.—It is the converse of the general problem of levelling, which is to find the difference of heights of two given points. *This* consists in determining the place of a point of any *required* height above or below any given point.

To do this hold the rod on some point of known height above the datum level; sight to it, and then determine the height of the cross hairs. Subtract from this the desired height of the required point, and set the target at the difference. Hold the rod at the place where the height is desired, and raise or lower it till the cross-hair bisects the target. Then the bottom of the rod is at the desired height. Usually a peg is driven till its top is at the given height above the datum.

To Locate a Level Line.—This consists in determining in the ground a series of points which are at the same level, *i.e.* at the same height above some datum. Set one peg at the desired height, as directed above. Sight to the rod held thereon, and make fast the target when bisected. Then send on the rod—the desired direction, and have it moved up or down the slope of the ground until the target is again bisected. This gives a second point; so go on as far as sight can be correctly taken, keeping unchanged the instrument and target. Make the last point sighted to a "turning-point." Carry the instrument beyond it, set up again, take a B. S., and proceed as at first.

The rod should be held and pegs driven at points so near together that the level line between them will be approximately straight.

Contouring.—Contour lines in hilly districts are usually made 100 feet apart; in lower districts the principal lines are in the 6-inch Ordnance map at 50 feet apart with intermediate lines between. Contour

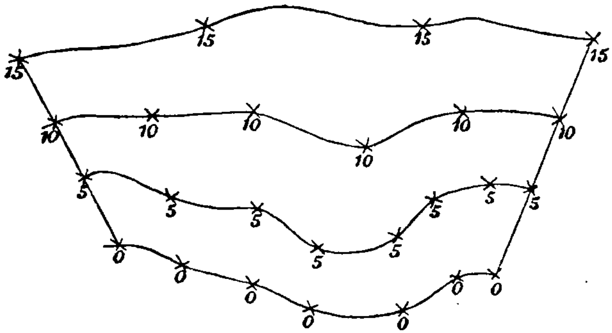


Fig. 51.

lines show the general figure of the surface, and therefore are of little use for the construction of sections if they are at wide intervals. In Fig. 51, the contour lines are 5 yards apart.

Methods for Determining Contour Lines.—They are of two classes:—1. Determining them on the ground at once; 2. Determining the highest and lowest points, and thence deducting the contour lines.

First Method. General Method.—Determine one point at the desired height of one line, and then "locate" a line at that level. The "reflected hand level," or "reflecting level," or "water level," are sufficiently accurate between "bench mark," not very distant.

One such line having been determined, a point in the next higher or lower one is fixed, and the preceding operations repeated.

On a long narrow strip of ground, such as that required for locating a road, run a section across it at every quarter or half mile, about in the line of greatest slope. Set stakes on these sections at the height of the desired contour lines, and then set intermediate points at these heights between the stakes. These sections *check* the levels. *On a broad surface,* level around it, setting stakes at points of the desired height, and then run sections across it and from them obtain the contour lines as before.

The external here serve as checks to the cross lines.

The contour lines may be surveyed by any method.

Contouring with Plane Table.—It is used to map the points as soon as obtained.

Second Method. General Nature.—This method consists in determining the height and position of the principal points, where the surface of the ground changes its slope in degree or in direction—*i.e.* determining all the highest and lowest points and lines, the tops of the hills and bottoms of hollows, ridges and valleys, &c., and then, by proportion or interpolation, obtaining the places of the points which are at the same desired level. The heights of the principal points are found by common levelling, and their places fixed by their heights being written upon them.

The first method is more *accurate*; the second is more *rapid*.

Cross Levels.—These show the heights of the ground on a line at right angles to the main line. They give "cross-sections" of it. They may be taken at the same time as the other levels, or independently. In taking "cross levels" where the slopes are steep, as in mountain districts, frequent settings of the instrument are necessary, unless "cross-section rods" are used.

Levelling for Sections.—The object of this is to measure all the ascents and descents of the line, and the distances between the points at which the slope changes, so that a section or profile of it can be made from the observations taken.

A section is a continuous line of levels in which distances as well as heights are measured.

The three principal parts of a section are (1) the datum-line; (2) the natural surface of the ground; (3) the line of proposed work. The datum point must be near the terminus of the line of works, and not near the middle of the line.

In *drawings of sections* the *vertical scale* should be vertical on the paper, owing to the irregular expansion and contraction in different directions. The scale of *distances* is divided into miles and furlongs, and these when necessary into chains and tenths of a chain, &c.

The vertical measures in the section must be written in figures; the gradients must also be written, and the changes of gradient marked; as also the greatest depth of cuttings and the greatest height of embankments.

The quantities of earthwork should be calculated from the field-book, and not measured on the paper.

Working Sections.—A working section is a definite profile of the ground, and the levels taken to form this section are termed permanent levels. The heights are taken at every chain from the top of stumps that have previously been driven in, and every minutiæ is particularly defined, such as the tops of banks, depths of ditches, watercourses, roads, pits, &c. A working section should state in writing the level of the ground, and the proposed work, and height of embankment or depth of cutting, at every point whose level has been taken. Those quantities should be found by calculation, not by measurement on paper. The positions and levels of bench marks should also be stated. For working sections every level should be checked.

Trigonometrical Levelling.—This consists by means of a theodolite or transit instrument in measuring the vertical angle between the zenith of the station occupied and the distant object the height of which is to be determined. The horizontal distance to this object must be known, and the measured angle must be increased on account of *refraction*, which may be taken roughly as proportioned to the length of arc of junction, and ordinarily equal to about $\frac{1}{14}$ of the corresponding angle at the earth's centre. We may either measure double the zenith distance—one half of the operation with position of theodolite, say circle left, the other half with circle right (the instrument having been turned 180° in azimuth)—or, if the zenith point (or horizontal point) of the vertical circle be previously determined, it will suffice to measure the single zenith distance (or altitude, depression being a negative altitude).

Irrespective of other *adjustments for the theodolite,* those for *collimation*, for *verticality of the vertical axis*, and for *horizontality of the horizontal axis* of the telescope must be carefully attended to. The observer should also examine the verticality of the plane of his circle to the last-named axis.

To Measure Horizontal Angles.—Set the transit so that its centre shall be precisely over the angular point. This is done by means of a plumb-line suspended from the centre of the instrument. Level the instrument carefully, sight to a rod, held at some point on one of the lines, as at B in the figure (A being the place of the

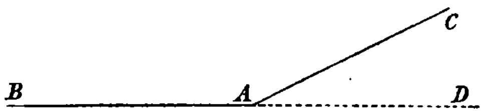


Fig 52.

transit), and note the reading. Then loosen the clamp of the vernier plate, keeping the other plate clamped; sight to a rod held at some point on the second line, as at C, and again note the reading. The difference of the two readings will give the angle B A C. This is the *angle of intersection.*

To measure the *angle of deflection,* D A C, *i.e.* the angle between A C and B A prolonged. After sighting to B, turn over the telescope. It will now point towards D, in the line B A prolonged. Note the reading; sight to C, and again note the reading. The difference of the readings will give the required angle.

Vertical angles are measured similarly to horizontal ones, only using the vertical instead of the horizontal circle.

Traversing.—In this method of surveying and recording a line, the direction of each successive portion is determined, not by the angle which it makes with the line preceding it, but with the first line observed, or some other constant line. The operation consists essentially in taking such back sight by the lower motion (which turns the circle without changing the reading), and taking each forward sight by the upper motion, which moves the vernier over the arc measuring the new angle, and thus adds it to or subtracts it from the previous reading.

Set up the instrument at some station, as B; put the vernier at zero, and, by the lower motion, sight back to A. Tighten the lower clamp, reverse the telescope, loosen the upper clamp, sight to C by the upper motion, and clamp the vernier-plate again. Remove

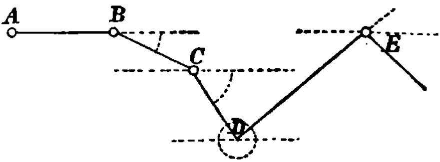


Fig. 53.

the instrument to C, sight back to B by the lower motion. Then clamp below, reverse the telescope, loosen the upper clamp, and sight to D by the upper motion. Then go to D, and proceed as at C; and so on. The reading gives the angles measured to the right or "with the sun," as shown by the arcs in the figure.

Barometric Levelling.—We need here only refer to the barometer as an instrument for measuring heights. In the form of a *mercurial barometer* it may be regarded as essentially a balance in which, under the influence of gravity, the mass of the superincumbent atmosphere is equilibriated by a mass of mercury. In the *aneroid barometer*, on the contrary, the atmospheric pressure is counterbalanced by the elasticity of a corrugated metallic vessel (generally filled with gas, sometimes supplied with a spring). A change of gravity could not, therefore, be indicated by an instrument of the first form, but would be by one of the second form. It is an instrument of great simplicity and portability, and depends on the known relation between the variations in the atmospheric pressure and the corresponding changes in the boiling-point of water. The results, however, are subject to considerable uncertainty.

CHAPTER IX.

UNITED STATES PUBLIC LANDS SURVEYS.

THE extensive territories of the United States are surveyed upon a peculiar system, planned with reference to the division of the land into squares of uniform size, so arranged that any tract of 160 acres may have its distinct designation and be readily found upon the map or recognised upon the ground by the marks left by surveyors.

These squares are bounded on the east and west sides by lines which are true meridians of longitude radiating from the north pole, and on the north and south sides by lines which are chords of the circular parallels of latitude intersecting such meridians.

In each land district a *principal meridian* line is run, extending through the entire district, and from this meridian, at points 24 miles apart, east and west, *base lines* are run, which also extend through the district. These lines are determined astronomically, and when located serve as axes to which the subdivisions of the district are referred.

Parallel to the axes, and on each side of them, other lines are run 6 miles apart, dividing the whole territory into squares, called *townships*, each containing 36 square miles, or 36 sections.

The meridians are drawn from the base lines north and south to the depth of two townships; but owing to their not being parallel, they do not meet—that is to say, the meridian drawn north from the first base line to the depth of two townships would not meet the meridian line drawn south from the second base, thus creating corners or offsets between the townships and section outlines, and making necessary a *correction line* at every distance of four townships apart, as shown on the index map.

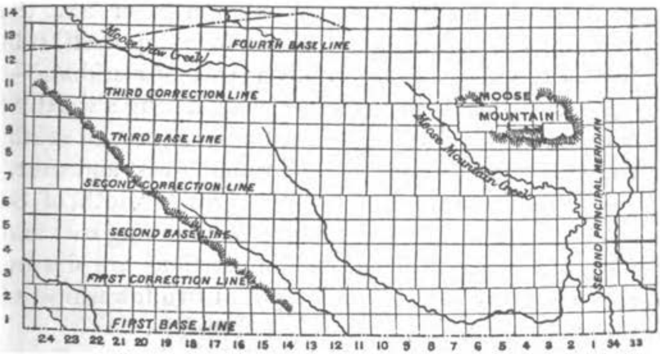


Fig. 54.

Townships.—A township measures, from centre to centre of the road allowances which form its actual boundary, 483 chains square (= 10,604 yards square), more or less, subject to the deficiency resulting from the convergence or divergence of the meridians, as the case may be, caused by the curvature of the surface of the globe.

The townships lying between two consecutive meridians 6 miles apart constitute a "range," and the ranges are numbered from the principal meridians, both east and west. In each range the townships are numbered both north and south, from the principal east and west line.

Thus if a township lies 12 miles east of the principal meridian, and 18 miles north of the principal east and west line, it is called township 3 N, range 2 E.

Each township is divided by meridians and east and west lines into squares having a mile on each side. These are called *sections*, and each contains 640 acres, more or less.

Sections.—Each township is divided into 36 "sections" of 640 acres (1 square mile) more or less, the exact area being, like that of the township itself, subject to the convergence or divergence of meridians—together with certain road allowances, having a width of one chain, on each section line running north and south, and on every other section line running east and west.

The sections are laid out the precise width of 80 chains, more or less, on the *base lines* running east and west, and the meridians bounding sections are drawn, both north and south, to the depth of two townships, to the "correction" lines already referred to.

All sections south of a base line will accordingly have their northern boundary lines rather more than 80 chains, while the north and south boundaries of sections in the townships laid off north of the same base line will correspondingly measure less than the normal dimensions of 80 chains. The difference, however, is practically inappreciable, as there is only about half a foot discrepancy between the northern and southern boundary of a quarter section—*i.e.* half a foot in a distance of half a mile.

The sections of a township are numbered from the S.E. corner, running along the southern tier of sections to No. 6, thence backward to No. 12, which lies exactly north of No. 1, and so on alternately, running from left to right and from right to left, to the north-easterly corner, which is No. 36.

The following diagram shows a township, as surveyed, with road allowance, and the manner in which the sections are numbered.

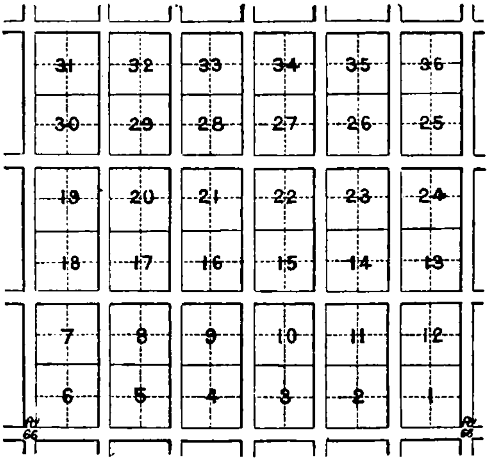
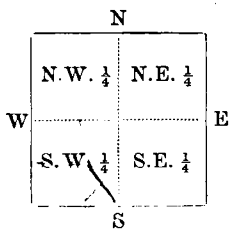


Fig. 55.

Legal Subdivisions of Sections.—Each section of a township is subdivided into "quarter sections," containing 160 acres each, or half a mile square, as shown in the diagram, and they are referred to respectively



as the N.E.$\frac{1}{4}$, the S.E.$\frac{1}{4}$, the S.W.$\frac{1}{4}$, and the N.W.$\frac{1}{4}$ of the section of which they form part.

The terms "half-quarter section," and "quarter-quarter section" are legal designations expressing the quantity of 80 or 40 acres respectively. In the latter case the quarter sections comprising every separate section are, in accordance with the boundary of the same as planted in the original survey, supposed to be further subdivided into four quarter-quarter sections, of 40 acres each, as shown in the following diagram :—

N

	13	14	15	16	
	12	11	10	9	
W					E
	5	6	7	8	
	4	3	2	1	

S

Posts and Mounds.—Surveyed lines on the prairie are marked by posts with mounds of earth built around them, as shown in Fig. 56.

Except in the case of correction lines, section posts and mounds are so placed that lines connecting the cardinal points of the compass will pass through their angles.

On correction lines they are placed square with the line.

In a timbered country the mounds are dispensed with, and the lines marked by blazing the trees on the side next the line and the direction in which it is run, the corners being established by wooden posts, the position of which are defined by bearing trees.

Only a single row of posts to indicate the corners of the townships or sections (except in correction lines)

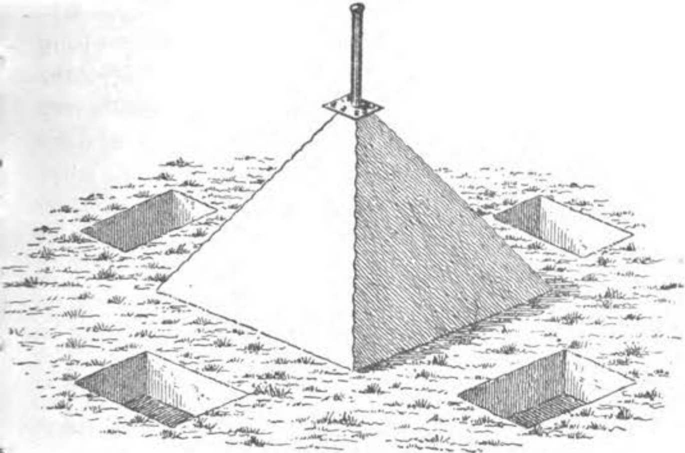
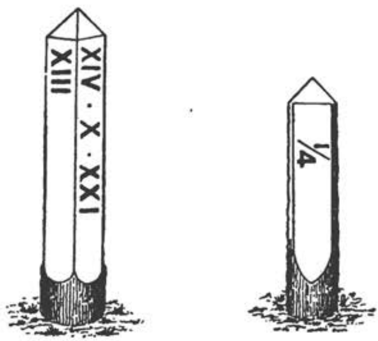


Fig. 56.

is placed on any surveyed line. These posts are placed in the west limit of road allowances leading north and



Figs. 57 and 58.

south, and in the south limit of roads leading east and west.

On correction lines posts are planted on each side of the road allowance, and marked independently for the township on either side.

It frequently occurs that a section corner falls into a lake, slough, or stream. In this case the surveyor builds a circular witness mound on the shore at

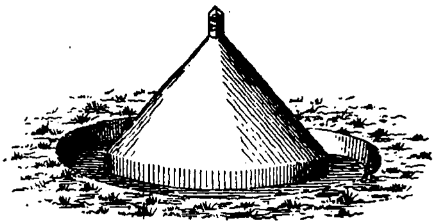


Fig. 59.

the point nearest to the true position of the section corner, the post standing in the mound being marked W.M., the bearing and distance to the site of the true corner being written thereon.

Post Markings.—Wooden posts are marked with Roman numerals cut into their faces.

Where iron posts are used, the figures are punched on a square plate of tin, which rests on the top of the mound, the post passing through its centre. In addition to the section numbers, the plates are marked with the letters N S E and W, and it is necessary in ascertaining the number of a section to see that the plate is turned so that these letters correspond with the cardinal points which they are intended to indicate.

Quarter section corners are designated by wooden posts, flattened on two sides. They are marked with the fraction $\frac{1}{4}$, and stand with their flattened sides facing the direction in which the section line is run.

The position in which the mounds and posts stand

Township 7 Range 15 W. 2nd Merⁿ

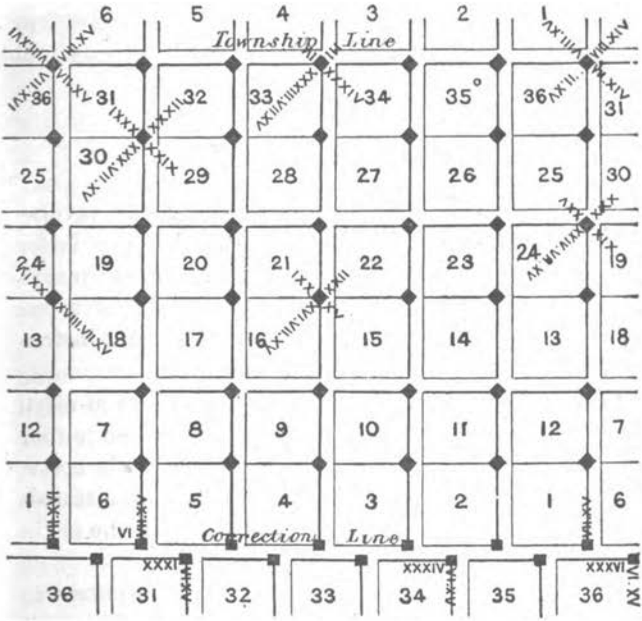


Diagram shewing manner in which posts are marked

Fig. 60.

with reference to the section lines, and the manner in which they are marked, is shown in the above diagram.

CHAPTER X.

LAYING OUT LAND.

Its Nature.—This operation is precisely the reverse of that of surveying, properly so called. The latter measures certain lines as they are; the former marks them out in the ground where they are required to be, in order to satisfy certain conditions. The same instruments, however, are used as in surveying.

Perpendiculars and *parallels* are the lines most often employed. The perpendiculars may be set out either with the chain alone, still more easily with the cross-staff or optical square, and most precisely with a transit or theodolite. Parallels may be set out with the chain alone, or with transit, &c.

To Lay Out Squares.—Reduce the desired content to square chains, and extract its square root. This will be the length of the required side which is to be set out by one of the methods indicated above.

An *acre* laid out in the form of a square is frequently desired by farmers. Its side must be made $316\frac{1}{4}$ links of a Gunter's chain, or $208\frac{71}{100}$ ft., or $69\frac{37}{100}$ yds. It is often taken at 70 paces.

The number of plants, loads of manure, &c., which an acre will contain at any uniform distance apart can be at once found by dividing 209 by this distance in feet, and multiplying the quotient by itself, or by dividing 43,560 by the square of the distance in feet. Thus, at 3 feet apart, an acre would contain 4,840 plants, &c.; at 10 feet apart, 436; at a rod apart, 160, and so on. If the distance apart be unequal, divide 43,560 by the product of these distances in feet; thus, if the plants were in rows 6 feet apart, and the plants in the rows were 3 feet apart, 2,420 of them would grow on one acre.

To Lay Out Rectangles.—The content length being given, both are measured by the same unit, divide the former by the latter, and the quotient will be the required breadth. Thus, 1 acre or 10 square chains, if 5 chains long, must be 2 chains wide.

The content being given, and the length to be a certain number of times the breadth. Divide the content in square chains, &c., by the ratio of the length to the breadth, and the square root of the quotient will be the shorter side desired, whence the larger side is also known. Thus, let it be required to lay out 30 acres in the form of a rectangle three times as long as broad. 30 acres = 300 square chains. The desired rectangle will contain 3 square each of 100 square chains, having sides of 10 chains. The rectangle will therefore be 10 chains wide and 30 long.

An *acre* laid out in a rectangle twice as long as broad will be 224 links by 448 links nearly, or 147½ ft. by 295 ft., or 49⅕ yds. by 98⅔ yds. 50 paces by 100 is often used as an approximation easy to be remembered.

To Lay Out Triangles.—The content and the base being given, divide the former by half the latter to get the height. At any point of the base erect a perpendicular of the length thus obtained, and it will be the vertex of the required triangle.

The content being given, and the base having to be m times the height, the height will equal the square root of the quotient obtained by dividing twice the given area by m.

The content being given and the triangle to be equilateral, take the square root of the content and multiply it by 1·520. The product will be the length of the side required. This rule makes the sides of an equilateral triangle containing *one acre* to be 480½ links. A quarter of an acre laid out in the same form would have each side 240 links long.

The content and base being given, and one side having to make a given angle, as B, with the base A B, the length of the side B C $= \dfrac{2 \times \text{ABC}}{\text{AB sin. B}}$

Example.—Eighty acres are to be laid out in the form of a triangle, on a base, A B, of 60 chains, bearing N. 80° W., the bearing of the side B C being N. 70° E. Here the angle B is found from the bearings to be 30°. Hence B C = 53·33. The figure is on a scale of 50 chains to 1 inch, = 1 : 39,600.

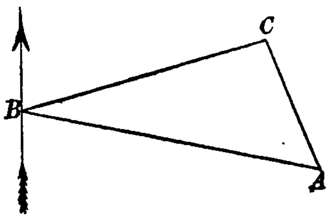


Fig. 61.

Any right-line figure may be laid out by analogous methods.

To Lay Out Circles.—Multiply the given content by 7, divide the product by 22, and take the square root of the quotient. This will give the radius with which the circle can be described on the ground with a rope or chain.

A circle containing *one acre* has a radius of 178½ links.

A circle containing a quarter of an acre will have a radius of 89 links.

There is much truth in the proverbial advantage of a farm or estate lying within a ring fence. The inconvenience which arises from fields of one farm running into or lying in the middle of another farm is often very great, and it is still too common in England. There can be no excuse for it, certainly, where the farms belong to the same owner. Both that and irregularities in the boundaries should be rectified at the very first opportunity; and, if they are on different proprietors' lands, such glaring inconveniences should be made the subject of an excaulm, or exchange, in the interest of the owners as much as of the farmers.

As to the size of farms, both large and small ones have their fitness and utility; but grazing farms should be relatively larger than those devoted to tillage.

In the interior arrangements of the farm lands, a great consideration is to have the fields properly set off, not merely as regards the division of arable and pasture land, but so as to mark the different soils that occur in each. It makes all the difference sometimes in the working of the fields, and in the equally good yield of the crops if the divisions have been made as far as possible in conformity with the surface soils.

The old style of laying out farms in England—if style it can be called—cannot certainly claim much on the score of utility; and it is a true type of the falsely named picturesque, with its miry lanes, its wide straggling hedgerows and ditches, the land cut up into numberless misshapen fields, and here and there waste plots of ground that seem to have been left out of the general plan because they would not fit in anywhere.

There can be little doubt that enclosures are beneficial to a certain extent—in some districts more so than in others; but whatever the size and number of the enclosures, they should be laid out so as to utilize the whole of the ground that makes up the farm and is free for this purpose. And if the wasteful agriculture which is so strongly encouraged by an ill arrangement of the fields is to be fully avoided, the same principle must regulate the laying out of roads and buildings.

It must be confessed that there is little plan or precision in our field system. If the limits of the field are defined, and perhaps the boundary fenced, it is thought to be quite enough for the purposes of agriculture; and if the shape of the field is at all nearly square or rectangular, it is considered a very well laid-out piece of land.

But while it is proper that the size, shape, and boundary of the enclosure should be attended to, this does not supply the place of an interior arrangement of the fields. Only those who have tried the plan of marking out the whole field-surface in squares or divisions of fractions of an acre know its advantages, in point of accuracy and readiness in conducting almost every branch of field-work, and in making trials of seeds, manures, &c. We shall notice a few of the advantages arising from such a plan.

In the first place, it enables the farmer to see at a glance what quantity of field-work is done in a given time by the hands or teams employed, no matter what description of work they are at—hoeing, reaping, ploughing, manuring, or anything else; and it is, at the same time, a great help to a better inspection of the work done. It also facilitates and encourages the use of piece-work in the employment of field hands. A square can be taken up, worked off, inspected, and paid for at the rate agreed on per acre with a simplicity that compares favourably with the slipshod fashion of day hands at work without a gauge, or piece-workers whose task is an uncertainty until the ground is measured.

It likewise affords a ready facility for making experiments on a small scale with seeds and manures, for trying different modes of culture, and for ascertaining the weight of produce obtained from the land, or the weight of crop consumed in the feeding of stock. These are only a few of the advantages. The plan, when adopted, will be found convenient for many purposes besides those enumerated.

But the question is, How to lay out fields in small squares so as to provide these advantages. With the use of improved machinery it does not do to have ditches, nor even deep furrows, as the bounds of these squares; and otherwise, of course cropped land has to be marked out annually, or at least as often as the field is resown. It may be done, however, not by furrows, but simply by lining out the ground after the crop is sown, and then drilling in the lines, with a small hand single drill, a single row of the same seed as the crop may be—grass, corn, turnips, &c. The same variety of seeds will be quite visible in the lines, especially where otherwise throughout the field the seed-corn or grass was broadcasted; and in the case of root crops, it may be nicely arranged by drilling, say in a field of yellow turnips, swede-seed in the marked lines, &c.

The expense and trouble of marking out lines is very little, and is soon amply repaid. Let a man, or a man and a boy, line out the field as soon as it is sown, in *tenths* or *poles*, &c., as decided on. Then take the hand drill and run along the lines, first the length of the field, then across, drilling somewhat thicker in the lines than it was sown over the field. The lines must be kept perfectly straight; but if the ground is properly lined out first, that is easy to do. The rate at which a man and a boy will line and drill-mark a field will of course depend on its total acreage, and on the size of the divisions into which it has to be lined or marked.

Of course if a more permanent system of marking without loss of land could be devised it would be better; but until that is discovered no labour on the farm will be better bestowed than that given to forming the line divisions here indicated.

CHAPTER XI

ESTIMATING WEIGHT, QUANTITY AND VALUES.

A KNOWLEDGE of measuring solids is indispensable to the land agent, surveyor, and farmer, as the dimensions and weight of all materials and objects are calculated by it.

Mensuration of solids comprehends the measure by length, breadth, and thickness of all bodies, whether solid, liquid, or gaseous. The general rule is, to "find the area of one end, and multiply that by the length." This rule is of universal application, whether to earthwork, ricks of corn or hay, heaps of dung, of stone, or of burnt clay, and to timber, &c. The area of one end, or of one surface, whether the end, side, top, or bottom, is found on exactly the same principle as in ascertaining the superficial contents of land; and if the figure diminishes in the course of its length, as the top of a rick, or the trunk of a tree, the mean length or half is taken as a multiplier.

Weight of Cattle.—The rule for ascertaining the weight of an animal by measurement is to multiply the square of the girth by the length, and this product by the decimal ·238, which will give the weight of the four quarters in imperial stones.

To ascertain the dead-weight by weighing—multiply the live-weight by the decimal ·605, and the product will give the dead-weight of the four quarters in imperial stones.

It is simpler to ascertain the weight by measurement.

We here explain the calculation of the dimensions of an animal and the principle upon which it is founded, by which anyone may find the weight without the assistance of tables. The length and girth of the animal being measured—the first from the shoulder-top to the tail-head, and the second immediately behind the shoulder—these dimensions bring the figure of the animal into the form of a cylinder, or nearly so. The rule for finding the contents of a cylinder is to find the area of the end and to multiply that sum by the length. The common method is, to multiply the square of the diameter by ·7854 (the area of a circle whose diameter is unity), and this product by the length for the solid content. But in measuring cattle the girth or circumference, and not the diameter, is obtained; and as the rule for finding the diameter correctly from the circumference involves itself into long decimal multipliers, the process, especially when feet and odd inches are the dimensions, is complicated and tedious. The more simple method, therefore, is to multiply the square of the circumference by ·0795775,* and that product multiplied by the length gives the contents; which again multiplied by the established weight of a cubic foot or other measure will give the weight of the animal.

To find the proportional weight of a cubic foot, &c.: —Find, by the above rule, the number of cubic feet

* This number is obtained in the following way: The area of a circle equals the square of the circumference divided by four times 3·1416 (the circumference of a circle whose diameter is unity); or 1 divided by 12·5664 ($=4\times3{\cdot}1416$)$=$·0795775. Hence the square of the circumference multiplied by ·0795775 gives the area of the circle.

which the animal contains, and weigh the four quarters after it is killed, and the former divided by the latter would give the weight per cubic foot. Thus, if an ox measures 8 feet girth, 6 feet length: $8 \times 8 = 64 \times \cdot 0795775 = 5 \cdot 09296 \times 6 = 30 \cdot 55776$ cubic feet in the animal;* and if the four quarters of the killed animal weighed 91 stones 6½ lbs., this weight divided by the number of cubic feet in the animal gives the weight of a cubic foot. Hence 91 stones 6½ lbs. = $91 \cdot 4642857 \div 30 \cdot 5576$ give 2·993 stones per cubic foot. And this is the actual weight assumed for a cubic foot.

The calculation may be shortened. As ·0795775 and 2·993 are both constant multipliers in the operation, they may be multiplied together and the product used in one multiplier, thus: $\cdot 0795775 \times 2 \cdot 993 = \cdot 2381754675$. But ·238, or three figures only, may be near enough for a multiplier. Thus $8 \times 8 = 64 \times 6 = 384 \times \cdot 238 = 91 \cdot 392$, or 91 stones $5\frac{1}{2}$ lbs. (In place of ·238 some use ·24, which gives a higher weight.) Thus, then, to find the weight of a fat animal, multiply the square of the girth by the length, and that product by ·238, or take $\frac{238}{1000}$th part of it, or use any lower and more convenient denomination of the same value.

Another rule is to multiply the square of the girth by five times the length, and divide the product by 21, to get the weight of the four quarters; *i.e.* multiply the square of the girth by the length and take the $\frac{5}{21}$st part of the product for the weight. Now $\frac{5}{21}$ converted into decimals is ·23809523, which exactly agrees, in

* The calculation may be performed by duodecimals, or by reducing odd inches, if any, to decimals or fractions; or both length and girth may be reduced to inches, and then as above. To bring cubic inches to feet, divide the product by 1728.

as far as the decimal numbers necessary for the calculation are required, with the numbers we have given.

Weight of Hay-ricks.—Various modes may be adopted for determining this, but the only accurate one is by the use of the platform scales. The number of tons may be nearly determined by ascertaining the number of cubic feet or yards in the rick, and obtaining the weight per foot by actual weighing if necessary.

Weight per foot. lbs.	oz.		Yards to a ton.	Weight per foot. lbs.	oz.		Yards to a ton.
5	3	=	16	7	8	=	11
5	8½	=	15	8	4	=	10
6	0	=	14	9	3	=	9
6	6	=	13	10	5	=	8
6	14	=	12				

The number of yards per ton will depend on the solidity of settlement of the stack. If a good-sized stack has well settled, about 12 cubic yards to a ton will be fair.

The following rule will give the weight approximately by measurement.

With the tape measure the length and breadth, then the height to the eaves, and from the eaves to the top.

To calculate the quantity proceed thus:—

To the height from the ground to the eaves, add one-third of the height from the eaves to the top: multiply this sum by the breadth, and that product by the length. This will give the area in feet, which, divided by 27 (cubic feet in a yard), the quotient will be in yards. Divide this by 10 to bring it into tons.

1. *Example.*—Suppose a stack of hay 30 ft. in length, 20 ft. in breadth, the height to the eaves 14 ft., height from the eaves to the top 9 ft. Required the quantity in tons.

14 ft. height to the eaves
3 add $\frac{1}{3}$ of height to roof
—
17
20 breadth
—
340
30 length
—
Tons
27) 102,00 (377·7 $\div$ 10 = 37.7
81
—
210
189
—
210
189
—
21
—
27

20 cwt.
7
—
10) 140
—
14 cwt. = $\frac{7}{10}$ of a ton.

2. *Example.*—Required the quantity of hay in a stack, the dimensions of which are as follows:—

Height to the eaves	12 feet.
From the eaves to the top . .	9 ,,
Length	25 ,,
Breadth	14 ,,

Average compactness 10 yards to a ton. *Answer,* 19 tons 8 cwt.

Thatching.—Thatchers' work is measured by the square of 100 square feet.

1. To find the quantity of thatching on square or oblong ricks:—

Rule.—Multiply the width over the top from eave to eave by the length at the eaves, both in feet, and divide the product by 100 for the quantity in squares of 100 square feet. If the ends of the rick are thatched, add the breadth of the rick to the length for the multiplier.

Example.—Required the amount of thatching on a rick measuring 30 ft. over top from eave to eave, length of side 40 ft., and width at eaves 12 ft. *Answer,* $15\frac{60}{100}$ squares.

2. To find the quantity of thatching when the roof of the rick or stack is conical:—

Rule.—Multiply the circumference of the eaves by half the slant height, both in feet, and divide the product by 100 for the quantity in squares of 100 square feet.

Example.—Required the amount of thatching on a rick of 36 ft. circumference, 12 ft. slant height. *Answer*, $2\frac{16}{100}$ squares.

Measurement of Grain in a Bin or Heap.—Multiply the length, breadth, and depth in feet, and that product by 0·8. Suppose the bin is 20 ft. long, 4 ft. wide, and 6 ft. deep; this will give, when multiplied together, 480 cubic ft. To reduce this amount to bushels multiply by 0·8, which gives 384 in answer. It takes 2,150 cubic inches to make a straked bushel, and a cubic foot has 1,728 cubic inches; hence the bushel is to the foot as 5 to 4, which is the explanation of the use of the fraction 0·8.

Weight is the only true standard of the quality of corn. The heaviest wheat in the smallest compass will always yield the greatest proportion of flour, and the millers are so well aware of this that they always stipulate for a nominal measure to be made up to a certain specified weight; but the heavy corn will always be worth more than the same weight of lighter corn.

To measure Dung-heaps, &c.—Measure the length and breadth, and take three or four depths, according to the inequalities of the surface. The mean of these depths, multiplied by the length and that product by the breadth, will give the cubical content of the heap.

If the area is in feet, divide by 27, and the quotient will be the quantity in loads.

Example.—A dung-heap is 50 ft. long, 25 ft. broad, and of the different depths of $3\frac{1}{6}$, 4, $4\frac{1}{2}$, and 5 ft. Required the number of cartloads.

```
Ft. in.
 3  2
 4  0
 4  6
 5  0
 ------
4)16  8
 ------
 4  2 average depth.
```

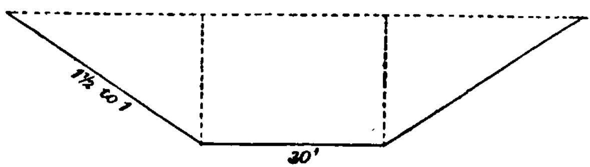
```
  Ft.
  50 length.
  25 breadth.
 ----
1250      ft. in.
   4 1/6 = 4   2 aver. depth.
 -----
5000
 208·3
 -----
27)5208·3(192·9 cartloads.
   27
   ----
   250
   243
   ----
     78
     54
    ----
     24·3
     24·3
    =====
```

Earthwork.—In calculations of earthwork we require to know three things—

(1.) The base.
(2.) The slope.
(3.) The depth of cutting or height of embankment.

In all rectilineal excavations, such as trenches, &c., or any other regular figure, the common rule will produce accurate quantities, as—

Multiply the length by the thickness and the product by the breadth. If the dimensions are taken in feet, to reduce it to cube yards, divide the product by 27. A cube yard of earth is equivalent to a load.



Example.—Given base of a cutting 30 ft., slopes $1\frac{1}{2}$ to 1, as in Fig. 62. Natural ground level transversely. Depths at intervals of 100 ft., as follows:—

Distances. (Feet.)	Depths. (Feet.)	Areas. (Sq. Feet.)
0	0	0
100	14	714
200	24	1584
300	30	2250
400	32	2496
500	24	1584
600	0	0

Calculate the sectional area in square feet; also the volumes in three divisions each of 200 feet long in cubic feet to the nearest whole number; also the total volume in cubic yards to the nearest whole number:—

(1.) AREA $= (30 \times h) + (1\frac{1}{2} \times h^2)$.

Area of section 0 = 0
„ „ 100 = 420 + 294 = 714 sq. ft.
„ „ 200 = 720 + 864 = 1584 „
„ „ 300 = 900 + 1350 = 2250 „
„ „ 400 = 960 + 1536 = 2496 „
„ „ 500 = 720 + 864 = 1584 „
„ „ 600 = 0

(2.) VOLUME $= x \dfrac{A. + 4A_1 + A_2}{6}$

Volume of first 200 feet of length

$$= 200. \frac{(714 \times 4) + 158}{6} = 148{,}000 \text{ cub. ft.}$$

Volume of middle length

$$= 200. \frac{1584 + (4 \times 2250) + 2496}{6} = 436{,}000 \text{ cub. ft.}$$

Volume of third length

$$=200 \quad \frac{2496 + 1584 \times 4}{4} = 294{,}400 \text{ cub. ft.}$$

(3.) THE TOTAL VOLUME IN CUBIC YARDS.

$$= \frac{148000 + 436000 + 294400}{27}$$

$$= \frac{878400}{27} = 32533{\cdot}32 \text{ cub. yds.}$$

Estimating the quantity of work which ought to be done in a given time by teams of labourers is an art that ought to be familiar to every agriculturist. In general no absolute rule can be laid down, because so much depends on soils, roads, cattle, and other circumstances; but in every particular case the rate or market price of labour per day being given, and the quantity of work ascertained which a man or a horse can fairly perform in a given time, a rate per square yard, pole, or acre, or per solid quantity of materials which are to be moved, can easily be determined on. A farmer should know by memory the number of ridges, or of single furrows or bouts, which it requires to make an acre on every field of his farm. This will aid him in every operation that requires to be performed on these fields, the quantity of manure, seed, ploughings, harrowings, hoeings, mowing, reaping, raking, &c., as well as in estimating the produce, whether corn, hay, roots, or the number of cattle or sheep that may be grazed there for any given time (Louden). It will be seen that the proper laying out of farm lands has a great deal to do with this.

Draining work, ditching and hedging, &c., ought to be subjected to similar calculations, so as, if possible, to let out all work not performed with the master's own men and cattle, by contract or quantity, instead of by time. As spade work is nearly the same in most parts of the country, certain general rules have been laid down which, though seldom strictly followed up, it may be useful to know. Thus in moving soil, as in digging a drain or the like, if the soil is soft and no other tool than the spade is necessary, a man will throw up a cubic yard of 27 solid feet in an hour, or 10 cubic yards in a day. But if picking be necessary an additional man will be required, and very strong gravel will require two. The rates of a cubic yard, depending thus upon each circumstance, will be in the rates of the arithmetical numbers 1, 2, 3, so that if a labourer earns 3s. 4d. a day the cost per cubic yard will be 4d. in the first case, 8d. in the second case, and 1s. in the third case.

Measurement of Timber.—It is desirable that a regular and recognised method of measuring be adopted, and the simplest and easiest way is to take the whole length of the tree to the height where it girths 26 inches round the bark. Then take the mean girth of the tree between this point and the base. If the measurement is taken outside the bark, one inch should be allowed for every foot of circumference. In practice, I girth the standing tree at 6 feet from the ground, which gives the medium girth of the lower 12 feet; then compute by sight the upper part of the tree, which a little experience soon enables any one to do sufficiently near for all practical purposes.

Before commencing to measure, the forester provides himself with a foot-rule and slide, leather strap marked or graduated, a pole, a marking axe, and a red lead pencil, or a small brush and paint.

The strap may be any convenient length, from 15 to 20 feet, $\frac{3}{4}$ inch broad, and of the strength of a small bridle-rein, with a piece of lead attached to one end of it. Previous to marking the strap with the necessary figures, the leather should be alternately wetted and dried, otherwise it is apt to shrink and expand when in use, according to the state of the weather. A seasoned gig-rein, when reduced to proper dimensions, forms an excellent strap. Such straps are not generally to be bought in the shops, but must be home-made.

6 being the last figure upon the strap, is exactly 26 inches from the end, including the lead and is the side of the square. The next figure is 7, and so on. The cross stroke indicates half inches, and quarter inches are indicated by the dot.

The pole used for taking the height is 14 feet long, marked *ft.* and *half ft.* The lowest mark is at 6 feet, at which height the trees are mostly girthed. Thus, by an expeditious and simple process the contents of the first 12 feet of the trunk are found. This is a ready method of measuring standing timber either for sale, transfer, or other purposes.

Though the use of the slide-rule is recommended for casting up the contents of a tree, yet in extensive practice it is seldom used. Having the length of the section (or whole tree) as indicated by the pole, and the side of the square as shown by the girth, the relative contents soon become so familiar that no casting up is required.

In making the strap it is advantageous to mark one side with white paint for measuring peeled timber, when no allowance is made for the bark; thus the side of the square of a tree *three feet* (3 feet) in girth is 9 inches. The other side may be marked with red paint, allowing for bark at the rate of 1 inch to the foot in girth.

The true and full content of a round tree can be found very nearly by Dr. Hutton's rule, which is—

Multiply the square of one-fifth the mean girth by twice the length.

Take a tree 44 in. in girth and 32 ft. long,

$$8{\cdot}8^2 \times \frac{64}{144} = 34{\cdot}41 \text{ cubic ft.}$$

But rough timber is never bought and sold by this rule, for it allows nothing for loss and waste in squaring the tree. In order to provide for that, another rule of measurement is adopted in practice, and it is this—

Multiply the square of the quarter girth by the length, and take the product for the volume. Thus the above tree gives by this rule—

$$11^2 \times \frac{32}{144} = 26{\cdot}88 \text{ cubic ft.,}$$

or little more than three-fourths of the full content of the tree. It is often urged against this rule that it allows more than is needed to make good the loss in squaring the tree, but it may be shown that it gives a higher result than the tree can actually be hewn to. It assumes that the quarter-girth and the side of the inscribed square are equal, whereas it is self-evident that the inscribed square is less than the circle. The greatest square a tree 44 inches in circumference can be hewn to is 9·9 inches, instead of 11 inches, as is assumed by the common rule of the quarter-girth, and therefore the actual volume of squared timber in the tree is only

$$9{\cdot}9^2 \times \frac{32}{144} = 21{\cdot}76 \text{ cubic ft.,}$$

or 5·08 cubic ft. less than by the quarter-girth rule. The true squared content will, therefore, be fully 36 per cent. less than the full content of the unhewn tree.

This great difference may very well be more than will cover the actual cost of and loss by squaring, if the slabs and chips are saleable, as they generally are, and hence practice has adopted a rule which, although erroneous in itself, gives something between the two, and for general use is the most fair one as between buyer and seller.

In measuring standing timber there is very little difficulty: use a ladder and pole for the length, and take the girth in three or four places.

A *cord* of wood is 8 ft. long × 4 ft. wide × 4 ft. high = 128 cubic ft.

Valuing Plantations.—It can scarcely be said that any forester thoroughly knows his duties till he can correctly value the various crops of wood of different ages that are under his charge. There are various ways of doing this.

On taking charge of the woods and plantations on an estate, it is necessary, in the first place, to become acquainted with every individual plantation, great and small, on the estate, and to ascertain (1) the name by which it is known on the estate plan, and generally or locally as well; (2) the date of planting, and whether planted in spring or autumn, as that makes a difference of one year's growth; (3) the acreage; (4) the proportion of different classes or species of trees in the plantation; (5) the aggregate number of trees; (6) the total value of the trees; (7) the average annual growth each plantation is making at the time of inspection; in lineal feet or cubic contents; (8) the money value per acre of the annual growth of each plantation; (9) the transferable value per acre; (10) the highest prospective value the plantation is ever likely to attain.

To the value of the growth of all plantations of which the thinnings have not yet paid for the original outlay in forming the cost of thinning is added, but not when the thinnings have paid such outlay.

It may be necessary to explain how the various data are obtained, and especially how the number of trees upon the ground are ascertained.

A book of convenient size for the pocket is provided, and ruled horizontally but not vertically, which can best be done on the spot; and with the assistance of two men a line through the greatest length of the plantation is taken, the first man, or leader, calling out the species of each tree in the line as he comes to it—oak, ash, larch, spruce, &c.—and the second man intimating the distance in feet and inches between each two trees throughout the whole length of the plantation. The leading man also girths the tree as he goes up to it, always at 4 feet from the ground, intimating the figures, and walks on to the next tree. The line pursued is not direct, but zigzag, each tree being taken as arrived at. The valuer in the meantime is entering the various data in his book—such as species, distance, height, and girth—

Species.	Distance.	Height.	Girth.
Sp. (Spruce).	10	16	15
L. (Larch).	18	15	20
Bi. (Birch).	13	14	16

and so on.

The plantation is again traversed in other directions, and when the whole is done the various averages are taken, by adding all the respective measurements, and dividing the same by the number of them.

It is to be observed that the trees are girthed at 4 feet from the ground, at which the height over the bark is equal to the girth at the ground *minus* the bark. This applies only to such plantations as have been at least once thinned but are below timber size.

In dealing with plantations that have not been thinned at all, the practice is to go carefully through every part, and note the lengths of the last top growths, and the full height of the trees, to the number of about 800 to the acre—the quantity that should remain upon the ground after being thinned the first time.

The method of casting up the value of a young plantation is a matter of simple proportion, stated thus—If a plantation is valued prospectively at sixty years' growth to be worth £60 an acre, what ought it to be worth at forty years' growth?

Plantations below thirty years growth have the original cost of forming added or subtracted as the case requires, and those over thirty years, or such as have been sufficiently thinned, are simply valued according to their present or prospective worth.

No further revenue is expected from the thinnings of a plantation after thirty years old, but an equivalent benefit is derived from it, in the form of grazing for sheep or cattle, which is indeed often of more value than the thinnings.

This mode of valuing young plantations may be objected to on account of no allowance being made for interest on the original outlay, and no sum being set apart for rent. These, however, are included in the *one item* —viz. the value of the annual growth. Say, the annual value of the growth of a plantation is 20s. per acre; against this there is the ground-rent 7s. 6d. per acre, and *interest* on cost of planting, 70s. per acre at 5 per cent., = 3s. 6d., making altogether 11s. per acre chargeable against the 20s. worth of produce, and leaving 9s. per acre in favour of planting.

There are various ways of valuing mature timber and old plantations, but the only plan to be recommended is to take the quantity of measurable timber tree by tree, and put a price upon it according to the kind and quality of the wood.

The age at which a plantation will come to maturity and at which it should be cut down to yield most profit, is a question that admits of no general answer; for trees vary in growth and early maturity according to soil, situation, climate, &c., so that no fixed period of cutting can be generally applied to any class of trees grown in different places and under more or less varying conditions. Within the range of our own climate, however, the quality and depth of the soil that the tree stands in has more influence on the age of maturity than any other single circumstance. For it has been found that when an oak tree in good strong soil 2½ feet deep will cut most profitably at fifty years, in an equally good and strong soil 3½ feet deep the same tree requires about seventy years to come to maturity; and if the soil is 4½ feet deep, one hundred years; but in lighter and sandy soils of the same depths, the periods of maturing are lessened to forty, sixty, and eighty years. The hard-wood trees are all slow growers, and it is generally held that a hard-wood plantation requires sixty years to come to maturity. A fir plantation will be at its best in about half that time, or thirty years. Where the plantation is a mixed one, the relative quantity of fast and slow-growing trees, and the effect which the greater proportion of either will have on the time of average maturity, must necessarily be considered.

To Calculate the Cost of Buildings by the Square.—The dimensions of the different compartments are taken and the length of each multiplied by the breadth, so as to give their superficial areas; and an amount per square foot, or generally per square of 100 ft.—that is, 10 ft. each way—is assigned to each. But the same difficulty attends this mode of computation (as estimating by comparison), even perhaps to a greater extent, for the sum placed against each square must be guided entirely by what is supposed to be the value of the class of building (farm-house, cottage, steading, &c.) it is intended to erect.

Professor Kerr very properly varies the allowance per square in proportion to the cost, extent, and finish of the house, and begins at £40 per square (and upwards) for family rooms, and £28 for servants' rooms, of a house of about the value of £1,250, increasing to £100 and £50 per respective squares in a house estimated at £40,000.

His plan is to take the dimensions of every room and portion of the house internally, multiplying their relative length by the breadth, then squaring the floor-spaces of passages and stairs in the same manner, and adding to the total $\frac{1}{5}$th of the whole for walls and waste.

TABLE OF THE RELATIVE PROPORTIONS OF THE CIRCLE, ITS EQUAL AND INSCRIBED SQUARES.

1. Diameter of a circle	×	·8862	} =	the side of equal square.
2. Circumference	×	·2821	}	
3. Diameter	×	·7071	}	
4. Circumference	×	·2251	} =	the side of inscribed square.
5. Area	×	·6366	}	
6. Side of inscribed square	×	1·4142	=	the diameter of a circumscribed circle.
7. Side of inscribed square	×	4·443	=	the circumference of an equal circle.
8. Side of a square	×	1·128	=	the diameter of an equal circle.
9. Side of a square	×	3·545	=	the circumference of an equal circle.

CHAPTER XII.

WEIGHTS AND MEASURES.

LINEAL MEASURE.

Marked.			
inc.	12 inches	=	1 foot.
ft.	3 feet	=	1 yard.
yd.	$5\frac{1}{2}$ yards	=	1 pole.
pl.	40 poles	=	1 furlong.
fur.	8 furlongs	=	1 mile, *m.*

4 inches = 1 hand, 6 feet = 1 fathom, 3 miles = 1 league.

Inches.		Foot.								
12	=	1		Yard.						
36	=	3	=	1		Pole.				
198	=	$16\frac{1}{2}$	=	$5\frac{1}{2}$	=	1		Furlong.		
7920	=	660	=	220	=	40	=	1		Mile.
63360	=	5280	=	1760	=	320	=	8	=	1

The inch is divided by mechanics into halves, quarters, 8ths, and 16ths. It is also divided into 10ths, and into 12ths, called lines.

Land is measured by the Imperial chain of 100 links = 66 feet, and therefore 1 link = 7·92 inches.

In geographical and nautical measurements, 60 minutes = 1 degree = 60 geographical miles. But 360 degrees = the circumference of a circle; therefore the mean circumference of the earth being 24,856 English miles, 1 degree = $69\frac{2}{25}$ English miles, or 60 geographical miles.

Measures of Surface, or Square Measure.

By square measure is meant length and breadth taken together. Thus, 1 foot, or 12 inches long by 12 inches broad = 12 × 12 = 144 square inches = 1 square foot, &c.

Marked.		
sq. inc.	144 square inches	= 1 square foot
sq. ft.	9 square feet	= 1 square yard.
sq. yds.	30¼ square yards	= 1 square pole.
pls.	40 square poles	= 1 rood.
rds.	4 roods	= 1 acre, *ac.*

Sq. In.		Sq. Ft.		Sq. Yd.		Sq. Pl.		Rood.		Acre.
144	=	1								
1296	=	9	=	1						
39204	=	272¼	=	30¼	=	1				
1568160	=	10890	=	1210	=	40	=	1		
6272640	=	43560	=	4840	=	160	=	4	=	1

An imperial acre = 10 chains long by 1 chain broad, 640 imperial acres = 1 square mile, 36 square yards = 1 rood of mason's work. A square of thatching, slating, roofing, flooring, and partitioning are each = 100 square feet.

Avoirdupois Weight.

For all goods sold by weight, except gold, silver, and jewels.

Marked.		
drs.	16 drams	= 1 ounce.
oz.	16 ounces	= 1 pound.
lb.	28 pounds	= 1 quarter.
qrs.	4 quarters	= 1 hundredweigh
cwt.	20 hundredweight	= 1 ton, *t.*

14 lbs. = 1 stone, 8 stones or 112 lbs. = 1 cwt

Drams.		Ounce.		Pound.		Qr.		Cwt.		Ton.
16	=	1								
256	=	16	=	1						
7168	=	448	=	28	=	1				
28672	=	1792	=	112	=	4	=	1		
573440	=	35840	=	2240	=	80	=	20	=	1

The pound avoirdupois is declared by statute equal to 7,000 troy grains.

Therefore	7000 lbs.	troy	=	5760 lbs. avoir.
or	175 „	„	=	144 „ „
and	175 oz.	„	=	192 oz. „

Hay and Straw.—36 lbs. of straw = 1 truss, 56 lbs. of old hay or 60 lbs. of new hay = 1 truss, and 36 trusses = 1 load; but straw and hay are generally sold by the stone or cwt. The hay of any year is considered new till the 1st of September.

Wool Weight.—7 lbs. = 1 clove, 2 cloves = 1 stone, 2 stones = 1 tod, 6½ tods or 182 lbs. = 1 wey, 2 weys or 364 lbs. = 1 sack, 12 sacks = 1 last; 20 lbs. = 1 score, 12 scores = 1 pack.

Solid or Cubic Measure.

In solid measure, length, breadth, and thickness are taken. Thus 1 foot, or 12 inches long × 12 inches broad × 12 inches deep = 1,728 solid inches = 1 solid or cubic foot, &c.

Solid In.		Solid Ft.		Solid Yd.
1728	=	1		
46656	=	27	=	1

40 solid feet of rough or 50 solid feet of hewn timber = 1 load.

Measures of Capacity

(For both liquid and dry goods).

Marked.		
gl.	4 gills	= 1 pint.
pts.	2 pints	= 1 quart.
qt.	4 quarts	= 1 gallon.
gall.	2 gallons	= 1 peck.
pks.	4 pecks	= 1 bushel.
bush.	8 bushels	= 1 quarter, *qr.*

Cub. Inch.		Gill.														
8·664	=	1		Pint.												
34·659	=	4	=	1		Quart.										
69·318	=	8	=	2	=	1		Gallon.								
277·274	=	32	=	8	=	4	=	1		Peck.						
554·548	=	64	=	16	=	8	=	2	=	1		Bush.				
2218·192	=	256	=	64	=	32	=	8	=	4	=	1		Qr.		
17745·536	=	2048	=	512	=	256	=	64	=	32	=	8	=	1		

42 gallons = 1 tierce, 63 gallons = 1 hogshead (hhd.), 84 gallons = 1 puncheon, 126 gallons = 1 pipe, 252 gallons = 1 tun.

The weights and measures in use should be imperial, and uniform in all districts, and apply to all commodities.

The variations of local weights and measures are so perplexing between corn and coals, hay and straw, wool and wheat, &c., that very few men of business even, if taken unprepared, can recollect the whole of them.

The 27th chapter of Magna Charta declares that the weights all over England are to be the same, but unnecessarily gives for different sorts of commodities two different sorts of weights—*troy* and *avoirdupois.*

The pound troy, consisting of 12 ounces, each ounce of 20 pennyweights, and each pennyweight of 32 *grains of wheat*, gathered in the middle of the ear, and well dried. The pennyweight has since been divided into 24 equal parts, called grains, and therefore weigh $1\frac{1}{3}$ grains of wheat each. Dr. Hutton, however, estimated the grain troy at $1\frac{1}{3}$ of wheat.

The avoirdupois, which from its more general utility is in greater use, has been computed by Dr. Hutton to contain 6,999$\frac{1}{2}$ grains troy; by Ferguson, 7,000; and by the academies of London and Paris, 7,004.

In dry measure, the following inconsistencies take place.

The *brass bushel* of Henry VII., found in the Exchequer in 1688, contained 2,145 cubic inches; and it being known by experience that 1,728 cubic inches of wheat weigh $58\frac{17}{576}$ pounds troy, the above bushel will, therefore, contain 72 lbs. troy of wheat, or 9 gallons weighing 8lbs. per gallon, and measuring $238\frac{1}{3}$ cubic inches each.

But, according to Greaves, in his "Origin of Weights and Measures," this same bushel, when filled with common spring water, and measured before the House of Commons in 1696, was found to contain $2{,}145\frac{6}{10}$ cubic inches, and the water weighed was equal to 1,131 ounces and 14 pennyweights, or 94 lbs 3 ounces and 14 pennyweights troy.

The Winchester gallon, measuring $272\frac{1}{4}$ cubic inches, contains 9 lbs. 13 ounces avoirdupois. But the Winchester bushel, legalised in 1697, measures $18\frac{1}{2}$ inches diameter and 8 inches in depth, and therefore contains $2{,}150\frac{42}{100}$ cubic inches, and its corresponding gallons should be $265\frac{8}{10}$ inches.

These are some of the inconsistencies in our present confused system of weights and measures.*

Measures of capacity are verified by ascertaining the weight of pure water they will contain at the temperature of maximum density (3·945° C., or 39·101° F.)

The verification of *measures of length* is made by means of what is called a comparator, a piece of mechanism upon which the bar to be verified may be placed, and determined in length by closely divided scales and verniers with microscopic observation, or by micrometers with finely divided screws, and large screw-heads divided on their circumference to one or more hundred parts.

* The Weights and Measures Act, which came into operation on January 1st, 1879, established the uniformity of weights and measures in the United Kingdom.

Metric Equivalents of Imperial Weights and Measures.

The units of the metric system are five, viz. :—

(1.) The *Metre*, the unit of length = 3·280899 feet = 39·37079 inches.

(2.) The *Are*, the unit of surface = the square of 10 metres = 119·60332 square yards.

(3.) The *Litre*, the unit of capacity = the cube of $\frac{1}{10}$ of a metre = 0·26418635 yards = 1·0567454 quarts = 2·1134908 pints.

(4.) The *Stere*, the unit of solidity = 1 cubic metre = 35·336636 cubic feet = 1·308764 cubic yards. This unit has fallen into general disuse.

(5.) The *Gramme*, the unit of weight = 15·43234874 grains troy.

Each unit has its decimal multiples and submultiples, *i.e.* weights and measures ten times larger or ten times smaller than the unit of the denomination preceding. These multiples and submultiples are indicated by prefixes placed before the names of the several fundamental units. The prefixes denoting multiples are derived from the Greek language, and are *deka*, ten; *hecto*, hundred; *kilo*, thousand; and *myria*, ten thousand. Those denoting submultiples are from the Latin, and are *deci*, tenth; *centi*, hundreth; and *milli*, thousandth.

The unit of itinerary measure is the *kilometre* = 0·62138 miles.

The unit of land measure is the *hectare* = 2·47114 acres.

The unit of commercial weight is the *kilogramme* = 2·2046425 lbs. avoirdupois.

To change *French grammes* into *lbs.* (avoir.) *Eng-*

lish, we have only to multiply the number of grammes by ·0022. To change *kilogrammes* into *cwts.*, multiply by ·1969. To change *lbs. English* into *kilogrammes French*, multiply by ·4535. To change *gallons* into *litres*, multiply by 4·543. To change *cubic inches* into *litres*, multiply by ·0163.

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