PATTERN-MAKING.

PATTERN MAKING

A Practical Treatise

EMBRACING THE

MAIN TYPES OF ENGINEERING CONSTRUCTION

AND INCLUDING

GEARING, BOTH HAND AND MACHINE MADE, ENGINE WORK, SHEAVES AND PULLEYS, PIPES AND COLUMNS, SCREWS, MACHINE PARTS, PUMPS AND COCKS, THE MOULDING OF PATTERNS IN LOAM AND GREENSAND, ETC.,

TOGETHER WITH THE

Methods of Estimating the Weight of Castings

TO WHICH IS ADDED

AN APPENDIX OF TABLES FOR WORKSHOP REFERENCE

BY

A FOREMAN PATTERN MAKER

With upwards of Three Hundred and Seventy Illustrations

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PREFACE.

The contents of this volume are in the main a reprint of articles which have already had a world-wide circulation in the pages of the *English Mechanic.*

Some two years since I observed the frequent questions which appeared in that journal in reference to the present subject, and the idea occurred to me to throw some of the results of my own experience into the form of short articles for its columns. The editor kindly approved of my suggestion, leaving me free to take my own course as to the scope of the articles and the method of illustration.

The favourable reception accorded to those papers led me to think that they might form the basis of a book which might fill a useful place amongst our technical literature.

These articles, therefore, are now thoroughly revised and corrected, and expanded by the incorporation of new matter, additional sketches, and useful tables. A serviceable syllabus of contents and appropriate chapter headings, together with a copious index, will render the subject matter readily accessible to the reader.

The book in its present form, it is hoped, will be found a *vade mecum* of that trade in which I have been engaged, as apprentice, journeyman, and foreman, for the last five-and-twenty years of my life. To my fellow-workmen, to those draughtsmen who have lacked a training in the shops, to pupils pursuing their practical studies in our factories, to employers and managers in engineering works, to all, in short, who seek more than a mere smattering of knowledge relative to this, the first and most important branch of engineeering construction, I respectfully dedicate this volume.

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PATTERN-MAKING.

CHAPTER I.

INTRODUCTORY.

Pattern-making a trade of recent growth.—Advantages of Division of Labour.—Tools used in Pattern-making.—Contraction-rules.—Timber.—Proposed treatment of the Subject.

In that excessive specialisation of trades and industries—that necessary breaking up of many of the older and more typical handicrafts—which has been going on during the present century, pattern-making has become a distinct occupation. Fifty years since, the old race of millwrights were "all-round" men in the engineering firms. They could fit up a mill throughout, design its arrangements, both general and in detail, make the patterns of the cast-iron work, gear the mortise-wheels, chip and file the iron-toothed ones, weld a shaft, turn it in the lathe, forge levers, fit up the pedestals and bearings, line the shafting, and, in fact, do all the work that is now divided among half-a-dozen separate and distinct trades. Necessarily this meant the sacrifice of some special skill, the absence of a certain mechanical facility which results from the division of labour. But, taken as a body, they were better craftsmen, because more complete, than the mechanics who now do one thing, and one thing only. They were men of a strong representative character, skilful in the use of a few rough and ready tools, and equal to contingencies as they arose. The race, except in some isolated localities, has nearly died out. Now, the pattern-maker constructs the wooden models and gears the mortise-wheels; the fitter chips, files, and fastens different parts together; the planer, slotter, and shaper save the fitter's muscles, and the iron-turner prepares his shafts and bores his wheels. The fitter again and the

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erecter occupy distinct positions, while each individual workman besides usually excels only in some special branch of work.

But this division of labour has its advantages. Machinery has been cheapened, there is more beauty and finish about it, and it is capable of being turned out of hand much more rapidly than was possible under the old *régime*. More and more yet the tendency of the time is to division—specialisation of labour. Men doing one class of work alone acquire a skill, a facility in that particular branch, which can be acquired and preserved in no other way. And in this we are only borne along by the tendencies of the age in which we live. Science and the wide fields of knowledge yield no exception to this rule. Men in any and every walk of life can only acquire great distinction by moving in one groove. The boundless universe is fair and inviting; but each must be content to plough his own little furrow, glad if he accomplish worthy work before the night comes on.

Enough of preface—now to our art and trade of pattern-making. Tools and timber, two essentials, may be disposed of briefly. Speaking generally, carpenters' tools are suitable for pattern work, but mortise-chisels are not wanted, neither are the plough and irons, nor the various bead and moulding-planes. And instead of a number of firmer chisels and gouges, long chisels and gouges, called paring-tools, are requisite. The average kit of a pattern-maker should consist of the following articles, though many workmen add largely to these: hand-saw, tenon, dovetail, bow, compass, and keyhole saws; jack-plane, trying and smoothing planes; about eight round planes, ranging from Nos. 4 to 18; three rebate-planes of various widths; thumb-plane, bull-nose and compass planes; half-a-dozen paring chisels of various widths, ten or twelve paring-gouges of various widths and sweeps, half-a-dozen firmer-chisels from $\frac{1}{16}$th to $1\frac{1}{2}$ inches; two short marking-gauges and a panel-gauge, a brace and set of thirty-six bits, two pairs of trammels, large and small respectively, wing compasses and dividers, calipers (inside and outside); axe, turning-gouges and chisels, round nose and side tools (about three of each); a six-inch and a twelve-inch trying-square, to which may be added a twenty-inch or twenty-four-inch one of wood; a bevel, sundry set squares, hammer, pincers, pliers, two spoke-shaves, brad-punches, gimlets, bradawls, oilstone, gouge-slips, mallet, screw-drivers, large and small, scriber, a few files, scales, and a standard and contraction-rule. Special mention must be made of this last tool, which is used only by pattern-makers. As its name implies, it is a rule which is made longer than the standard measure by the amount which cast iron contracts in cooling from the molten state to the ordinary temperature of the atmosphere. Though a standard rule is required for the measurement of castings, it would be obviously inconvenient to use it in pattern-making, because the workman would be perpetually making approximate allowances for contraction in fractional parts of a foot. So the contraction-rule economises his time and insures something more accurate than approximations. A two feet contraction-rule is nearly a ¼ inch longer than a common rule—strictly speaking, ¼ inch in 2 feet 6 inches. This represents nearly the maximum amount of contraction for iron, and is fairly correct for general work. But an experienced pattern-maker knows that he must not trust too much to his rule, but that special allowances are required for special classes of work, and for different qualities of metal as well as for different kinds of metal. Thus, while iron contracts an eighth in 15 inches, brass and steel contract an eighth in 10 inches, steel frequently rather more. A heavy casting will contract less than a light one, while a small casting will often come out as large, or even larger than the pattern. Hard white iron will contract much more than soft grey iron, and the presence of large dried cores in the mould will diminish the amount of contraction. A plate with large superficies will almost invariably come out *thicker* than the pattern, owing to the fluid pressure exercised by the *head* of the runner, and also to the top-part box not being entirely rigid. Experience alone can guide in these matters; and some element of uncertainty will always be present, for different mixtures of metal will show different contractions, as also will rapid or steady lowering of the temperature in the cooling of castings. But in general, for castings of moderate size, the contraction-rule is practically correct. Few men provide themselves with a contraction-rule specially for gunmetal and brass. Rules are sometimes made having the divisions for iron contraction upon one edge and those for brass upon the other. But one is apt to make blunders in measurement where this is the case, and the safer way is to have a rule giving contraction for iron only, and to make the additional allowance for gunmetal when necessary —very approximately one and a half times that of iron, or ⅛ inch in 10 inches.

The timber used for ordinary patterns is yellow pine. It is light, soft, easy to work, comparatively free from liability to warp and twist, and it is cheap. Red deal and pitch-pine are unsuitable, since in the foundry sand they absorb moisture, and become ridged and rough, causing the mould to tear up when the pattern is withdrawn. They are, besides, not so pleasant to work up as the yellow pine. For small patterns mahogany is an excellent wood, hard, strong, and not liable to warp. Its price precludes its use except for small patterns, or patterns which have to be moulded repeatedly. Other woods are occasionally used, but these are the best, and are the ones in commonest demand.

Obviously the scope of such a work as this will not allow that much space should be occupied in the discussion of those matters which are learned by the apprentice during the first year or two of his time, and which in most cases could not be imparted except in the workshop. We are at least bound to assume that the readers of these pages are able to use their tools, and that they possess some little acquaintance with the internal arrangements of an engineer's factory.

Of glueing, varnishing, the allowances for fitting and machining, the taper on patterns for delivery in the sand, the use of cores and drawbacks, special tools, patterns for loam moulding, and so forth, we shall speak as occasion arises, thinking it better for the sake of variety to intersperse our remarks concerning these and other kindred matters amongst the articles themselves. It would be clearly impossible in the compass of a volume to instance every class of work and every contingency that might arise. What we purpose to do is, to take individual patterns of representative types, and while describing these in detail, to discuss, as occasion offers, the general principles to be borne in mind in the construction of each class of work. By bearing these first principles in mind no real difficulty need be experienced in dealing with exceptional cases, modified forms, and so on.

CHAPTER II.

ON DESIGNING TOOTHED WHEELS.

Shop Drawing-boards.—Importance of shaping Wheel Teeth correctly.—Typical Forms.—Definitions.—Cycloidal Teeth.—Willis's Odontograph.—Involute Teeth.—Proportion Scales for Cycloidal Teeth.—Rolling the Tooth Curves.—Choice of Circles.—Proportions of Arms, Rim, and Boss.—Building-up of Patterns.—Ring Segments.—Jointing.—Pegging.—Remarks on Turning Tools.—Mode of Use.

WE suppose we have to make a pair of cog-wheels which shall work correctly and smoothly into one another, and which shall neither look clumsy on the one hand nor break at the first occasion of stress on the other. Before attempting to make the pattern, then, we should draw the wheels out to full size. In the case of large wheels this is done on a drawing-board—not the board of the office draughtsman, but the workman's board, made by laying several very dry pieces of stuff together edge to edge, and retaining them in place with battens screwed on the back. The face is then planed nicely over with a smoothing-plane, and whitened with chalk. The edges are shot straight and at right-angles with each other, so that a T-square may be used from either edge. There are dozens of these boards of various sizes in every well-appointed pattern shop, it being frequently desirable to retain drawings for reference until after the castings are made. It is usually the foreman's duty to strike out the work on the boards. Of course, perspective drawings cannot be available for measurement; hence working drawings must be projections, consisting of plans, elevations, and vertical and horizontal sections. All save the simplest jobs should be struck out thus. This practice will frequently prevent mistakes, and enable the workman, by a clearer understanding of the details and relationships of mutual parts, to economise both time and timber.

Given the drawing-board, there comes the important question how to design the wheels. Sometimes this is done in the drawing-office, sometimes by the foreman of pattern-makers, Yet every workman should be able to design his own wheels in a proper fashion. He will naturally also and properly regard the teeth as meriting the first attention. On the shape of these depends the smooth working of the wheels and in general their durability also. Teeth of almost any shape will manifestly work together if sufficient clearance or space between their contiguous flanks be allowed. Teeth may work together by a succession of jerks, or they may glide smoothly over each other's flanks in constant contact. Teeth of large pitch may be relatively weak, while teeth of small pitch may be relatively strong; each according to design. Also a form of tooth suited for one class of work will not always be so suitable for another class. Hence the propriety of devoting to the forms and proportions of teeth a considerable amount of attention and care.

There are two typical forms in use for the teeth of wheels, viz. epicycloidal and involute. There is also that close approximation to the true epicycloidal form known as the odontograph. The involute is only suitable for use where the wheel-shafts have varying centres, as in rolling mills. In general engineering, the epicycloidal is the best and most durable form of tooth, far preferable to any mere rule-of-thumb design. It is strong, elegant, works easily, and lasts good for a long time—that is if it be struck out carefully and with proper judgment. Now, it is the simplest thing in the world to strike out an approximate epicycloidal tooth that shall work with those of any other wheel, or any number of wheels, if one clearly understands the process. Before entering, therefore, into the description of the construction of their patterns, it will be well to explain the methods of the designing of cycloidal and involute teeth.

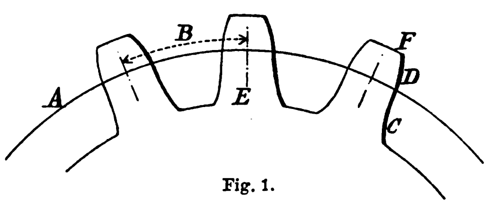


Fig. 1.

As a matter of course, in a technical work no apology will be necessary for explaining the meaning of terms and things which are perfectly well understood by experienced workmen. There are, therefore, a few terms which I must explain before going further. "Pitch-line" (Fig. 1, A) of a wheel is its circumferential line of teeth centres, which is in contact with, but does not intersect, the pitch-line of the wheel into which its teeth work. Theoretically, the teeth are only an accident of the wheel, a form of construction necessitated by circumstances; the ideal wheels are supposed to work by the friction of their smooth peripheries, those peripheries being considered as coincident with the pitch-lines. "Pitch" (Fig. 1, B) of a wheel is the distance from the centre of one tooth to the centre of its fellow measured on the pitch-line, which distance must be constant all round; "flanks" (Fig. 1, C) are the sides of the teeth lying below the pitch-line; "faces" (Fig. 1, D) extend from the pitch-line outwards; "root" (Fig. 1, E) is that portion of the tooth which meets the periphery of the rim; "point" (Fig. 1, F) is the opposite or extreme end of the tooth; "cycloid" is a curve drawn by a point in the circumference of a circle rolling on a straight line; "epi-cycloid" is the curve formed without, hypo-cycloid that formed within, the fundamental line or circle. Epi-cycloid is, however, the general term applied to the teeth formed by a generating circle rolling without and within the pitch-lines of wheels and racks. The one essential condition in order that any two or more wheels of a set shall gear smoothly together, is that a single describing circle be used both for points and roots of each of the wheels in the set. Where two wheels only are designed to work together, we may select a describing circle with a view to strength alone, a small circle spreading the flanks and making a broad root. But where a whole train of gearing is wanted, or where "stock" wheels are of necessity required interchangeable, the circle must be chosen with reference to the smallest wheel in the set, and must never exceed the radius of its pitch circle. Where this radius is taken as the basis (usually that of an eleven or twelve-toothed pinion) the tooth flanks become radial from the centre and the roots are weakened thereby. Still, as the roots can in most instances be strengthened by shrouding, the inconvenience is not so serious as it appears at first sight.

In striking special pairs of wheels, of course it is not necessary to use the same describing circle throughout. It is in those cases only essential to bear in mind that the same circle which strikes the roots of the wheel must strike the points of the pinion, and conversely.

The working out of the curves necessary for every separate

Fig. 2.—The Odontograph.

TABLES SHOWING THE PLACE OF THE CENTRES UPON THE SCALES.

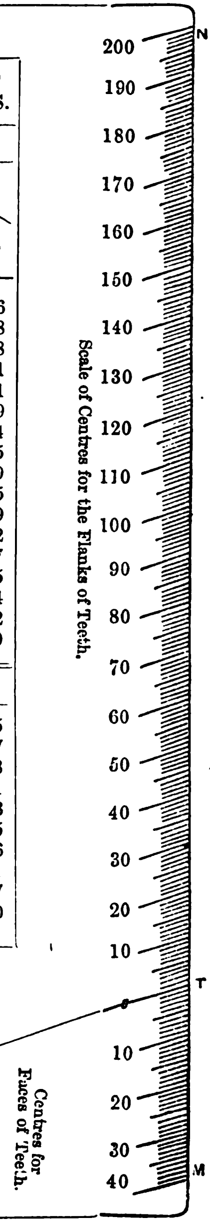
CENTRES FOR THE FLANKS OF TEETH.

Number of Teeth.	Pitch in Inches.							
	1	1¼	1½	1¾	2	2¼	2½	3
13	129	160	193	225	257	289	321	386
14	69	87	104	121	139	156	173	208
15	49	62	74	86	99	111	123	148
16	40	50	59	69	79	89	99	191
17	34	42	50	59	67	75	84	101
18	30	37	45	52	59	67	74	89
20	25	31	37	43	49	56	62	74
22	22	27	33	39	43	49	54	65
24	20	25	30	35	40	45	49	59
26	18	23	27	32	37	41	46	55
30	17	21	25	29	33	37	41	49
40	15	18	21	25	28	32	35	42
60	13	15	19	22	25	28	31	37
80	12	..	17	20	23	26	29	35
100	11	14	..	..	22	25	28	34
150	..	13	16	19	21	24	27	32
Rack.	10	12	15	17	20	22	25	30

CENTRES FOR THE FACES OF TEETH.

Number of Teeth.	1	1¼	1½	1¾	2	2¼	2½	3
12	5	6	7	9	10	11	12	15
15	..	7	8	10	11	12	14	17
20	6	8	9	11	12	14	15	18
30	7	9	10	12	14	16	18	21
40	8	..	11	13	15	17	19	23
60	..	10	12	14	16	18	20	25
80	9	11	13	15	17	19	21	26
100	..	..	..	..	18	20	22	..
150	..	..	14	16	19	21	23	27
Rack.	10	12	15	17	20	22	25	30

N B. This figure is half the size of the original.



wheel involves some little trouble and care; and in order to lessen this, and to ensure more perfect uniformity of results, the late Professor Willis, of Cambridge, invented the odontograph scale. This instrument furnishes the workman with approximate radii and centres for striking the faces and flanks of teeth. The annexed diagram, Fig. 2, represents the scale drawn to half full size, with some columns of small pitches omitted, and the method of its use is as follows:—

Say, for instance, we have a wheel of 24 teeth, 1½-inch pitch. We strike out the pitch-line, and the lines representing the points and roots of the teeth, Fig. 3. Then laying down a distance equal to the pitch, viz. 1½ inch, upon the pitch-line, we bisect this; which bisecting line will represent the side of a tooth. Draw lines from the points which represent the pitch centres to the centre of the wheel; call these lines A and B, and the line of bisection C. Now lay the slant edge of the scale against the line A, allowing the graduated edge at T (see Fig. 2) to cut the pitch-line there. Looking down the "scale of centres for the flanks of the teeth," we find opposite 1½-inch pitch and 24 teeth the number 30. So we place one leg of the compass against 30 on the graduated edge, for the flanks of the teeth, and set the other to the point of bisection, C, on the pitch-line, and strike our flank, *f*, with the radius so obtained. We then remove the slant edge of the scale to the line B, allowing the graduated edge at T, Fig. 2, to cut the pitch-line once more. Looking down the 1½-inch column of "centres for the faces of the teeth," and along the row marked 20 (that being the nearest to 24), we find the figure 9. The division 9, therefore, along the scale of centres for the faces of the teeth is the point whereon we set our compasses for striking that portion of the tooth above pitch-line, *g*, and the radius is taken as before to the point of bisection in C.

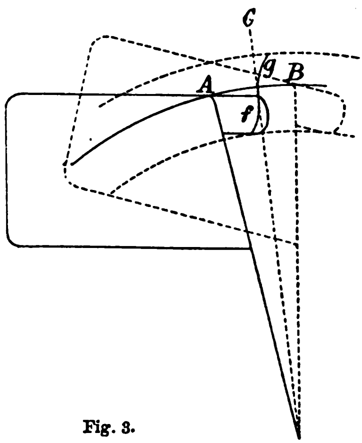


Fig. 3.

This scale is very useful, and a comparatively unskilful workman may be intrusted with its employment. When radii are required for wheels not in the list, it will be sufficient to take those intermediate between numbers given. The instrument is sold both in card and brass at the price of a few shillings.

We said that the involute form of tooth was only suitable for shafts with varying centres. Hence the pattern-maker is seldom required to construct this type of wheel. In these the path of contact of the teeth is always in the line of tangent to the base circle, and the outline of the tooth is, as its name implies, that developed by the unwinding of a cord from a base circle.

Assuming the pitch-circles of a pair of wheels to be given approximately (though we may say there is no pitch-circle in

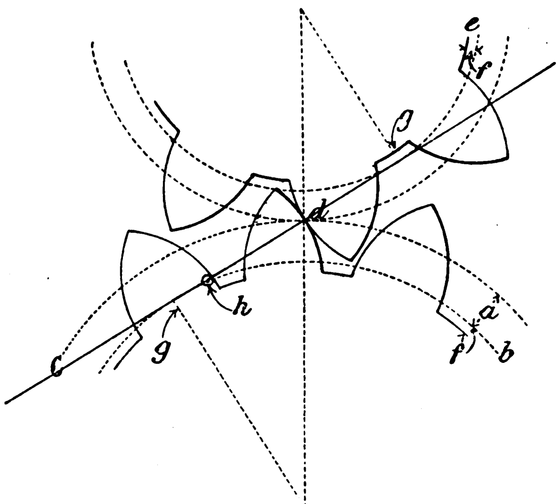


Fig. 4.

the sense in which the term is used in cycloidal wheels) the way to proceed in setting out is as follows:—Assume a working depth of tooth below pitch-line, Fig. 4, *a*, and strike a circle, *b*, concentric with the pitch-line on the larger wheel; draw a tangent, *c*, to that circle, cutting the pitch-line at *d*, and prolong it to about an equal distance beyond. From the centre of the smaller wheel strike a circle, *e*, cutting this tangent on the prolonged line, and this circle will give the working depth of the cogs of the smaller wheel. Bottom clearance, *f*, *f*, must be given below these base-lines.

The tooth flanks may be marked by a needle point stuck in the edge of a strip of wood, the latter being rolled around the base circle, just as a piece of string might be unwound from a cylinder. The curve being thus found, an approximate radius might be taken, and all the flanks struck from a line of centres. The centre for such a radius will be found at about one-fourth of the distance from *g* to *d* on the tangent line, or at *h* in the larger wheel.

If we find on trial that the points of the teeth of the wheel fall short of the base-line on the pinion, we must bring the base-line of the wheel nearer to the pitch circle, thus giving a higher angle to the tangent line, and in consequence producing a shorter tooth. The length of tooth is thus confined within certain narrow limits, and we may have to make two or three trials before we strike a fair average shape.

Returning to our cycloidal teeth, in which the interest of the pattern-maker chiefly centres, we require a fixed and uniform scale for their length. To some extent this is arbitrary—or perhaps we should say, experience has indicated the proportions which now obtain among engineers. The longer the tooth the weaker it becomes; but a short tooth, on the other hand, has less wearing surface.

The dimensions of wheel-teeth are invariably given in proportions of the pitch. These proportions embody the results of practical experience. Though different tables vary slightly, it is preferable, when a scale has been once adopted, to adhere uniformly to it. A scale can be constructed with a little care, and if preserved will save the trouble of marking out fresh proportions whenever a wheel requires to be made. Take a piece of paper and glue it on a board about 16 inches by 4 inches. When dry, line it out as in the diagram (Fig. 5). Divide one end into 15 equal parts; let lines from these divisions converge to a point 12 or 15 inches away. Now draw lines across of certain fixed lengths—½ inch, ¾ inch, 1 inch, and so on—and also lines for the odd eighths, ⅝ inch, ⅞ inch, &c., intermediate in position. These lines will represent the various pitches that may be required. Let them advance thus from ½ inch up to 3 or 4 inches. Now, on this scale the whole depth of tooth is represented by 12 divisions, the depth from pitch-line to root by 6½ divisions, and as a consequence the depth from pitch-line to point by 5½ parts. It is obvious that if the teeth were equidistant above and below the pitch-line, the points of one wheel would grind in the roots of the other. Hence the reason of bottom clearance. The thickness of the

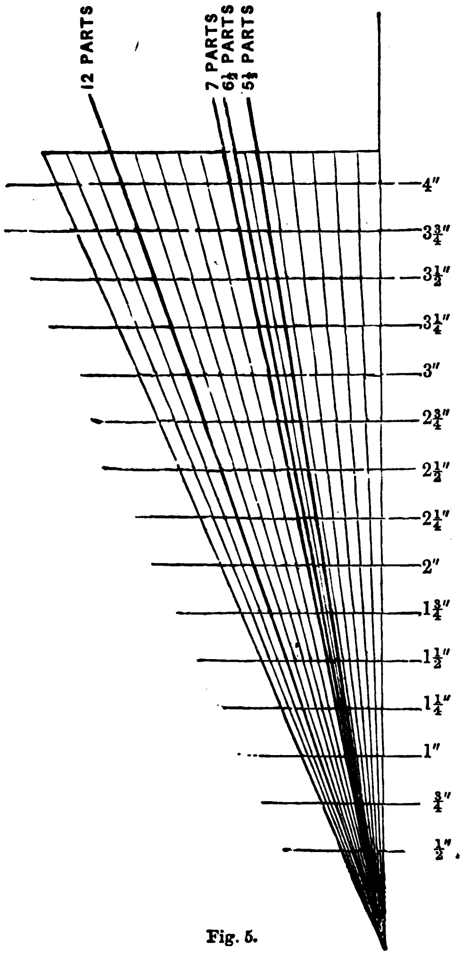


Fig. 5.

teeth is taken as equal to 7 parts. That leaves one part for flank clearance between contiguous teeth. These divisions may be indicated by deeper lines on the scale. This is a convenient and handy form of scale, and the proportions are good. Some authorities give rather more, some rather less, others give ratios varying slightly in the case of large and small wheels. A comparison of the proportions given in the works of Box, Unwin, Molesworth, and D. K. Clark will show some slight variations. It is of no consequence, however, which be adopted, so that the same proportions are always adhered to.

For the sake of clearer illustration, let us assume that we have to make a wheel of 75 teeth and 1¼ inch pitch, to gear into a pinion of 23 teeth. Our wheel will then be 2 feet 5⅞ inches, or for convenience say 2 feet 6 inches diameter upon the "pitch-line," and its pinion 9⅛ inches. Divide out the pitch circles struck in contact on the drawing-board into corresponding numbers of points—namely, 75 and 23—by means of the "spring dividers," the screw on the dividers permitting of more delicate adjustment than the ordinary quadrant compasses.

Now apply the proportions of the tooth scale to the wheel and pinion alike. Take 7 parts where the 1¼-inch line cuts the scale; that will be the thickness of our teeth. Take 5½ divisions on the same line; that will give the length of the points of teeth. Take 6½ parts, also upon the same line, and that will give the depth from the pitch-line to the root.

Having thus obtained length and thickness, we will proceed to strike out the teeth, and having already explained how to use the odontograph, we will now instead find our own cycloidal curves. Get two bits of wood an eighth thick, cut the edges of one to an inside and outside curve respectively, of the same radius as the pitch diameter of one wheel (Fig. 6); cut the other piece in like fashion to the pitch diameter of the other wheel, and lay one edge of each sweeped piece on its respective pitch-line. Now make a number of discs ranging from 1 inch up to 6 inches, advancing by a ¼ inch in diameter. Drive a needle into the edge of each at an angle of about 45° (Fig. 6), allowing the point to project beyond the edge sufficiently to make a scratch.

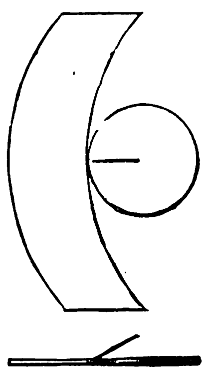


Fig. 6.

These are the rolling or generating circles, for the formation of the epi- and hypo-cycloidal curves. Take one of the discs, bearing in mind the remarks made in the last chapter relative to the choice of the generating circle, place the point of the needle against the inner edge of the sweep, and roll the disc along, exerting a gentle pressure downwards at the same time. The needle point will describe the flank of the tooth below pitch-line (Fig. 7, *a*). Obviously the diameter of the disc will regulate the breadth of the tooth below the pitch-line: a small disc will spread the flanks, making the root very broad; a large disc will make them inconveniently narrow and weak. For this wheel a 2⅜ or 2½-inch disc will give an elegant and strong root, and a disc of this size will be suitable for a constant describing circle for wheels of this pitch, taking a pinion of twelve teeth as the smallest of a set. Having now got the

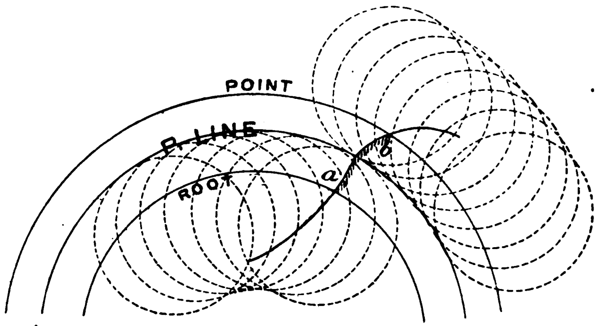


Fig. 7.

curve for the flanks of the teeth lying *below* the pitch-line in the large wheel, use the disc which generated them to strike the faces of the pinion teeth lying *without* the pitch-line. For that purpose lay the outer pinion sweep on its pitch-line, and roll the disc as before. The edges of the templets will now be reversed, and the faces of the wheels (Fig. 7, *b*) and the flanks of the pinion will be generated by the same circle. It may be noted that these curves, thus generated, are not perfect arcs of circles, but so infinitesimal is the deviation, that they are in practice struck with a compass. For having found, by trial, a centre for the best approximate radius, the flanks of all the teeth are struck uniformly with that radius. To insure accuracy in these centres, a line is struck from the centre of the wheel, passing through the centres of all the radii.

Wheels marked out thus are in constant contact, the flanks of the teeth roll smoothly one over the other, and a very small amount of clearance is necessary. Working easily, and being free from shock, they will last much longer than wheels made by rule-of-thumb practice, and will also produce less noise. We have considered our wheels as a portion of a set, and have therefore used the $2\frac{3}{8}$-inch circle for faces and flanks alike. But in making special pairs of wheels we can use two circles with advantage. Thus, if we wanted a very strong pinion, we might take a describing circle much smaller than the pinion radius, and so spread its roots. In making bevel wheels, which can gear only in pairs, we can adopt this expedient very well. Also in making a new wheel to gear with an old and perhaps badly shaped one, we shall discover first by trial what circles will strike the flanks and faces of the old one, and make our new one to correspond.

With respect to thickness of arms, rim, boss, &c., rules are somewhat arbitrary. Something will also depend on the special work the wheel has to do. But commonly these are also given in terms of the pitch, modified by diameter, breadth, diameter of shaft, &c. The number of arms in a wheel between 10 or 12 inches and 2 feet in diameter may be four; under 10 or 12 inches the wheel will be a plated or disc wheel. But this also will depend on pitch, for a 2-feet wheel of fine pitch should have half-a-dozen arms, while a wheel may be plated up to 2 feet in diameter if it be of a 3 or 4-inch pitch, and is carried by a large shaft. From 2 feet to 6 or 7 feet in diameter a wheel should have six arms; but if of larger diameter than that it should have eight or ten. The width of the arms measured nearest the rim may be roughly taken at twice the pitch; but the following formula from Box on "Mill-Gearing" is preferable:

$$\frac{7 \cdot 34 \times P \times W \times \sqrt{N}}{A} = B^2$$

Where

7·34 is a constant multiplier,
P = pitch,
W = width of wheel,
N = number of pinions which wheel has to drive,
A = number of arms.

The arms taper from the boss towards the rim about $\frac{3}{8}$ inch in width for every foot of length. The thickness of the arms, as also of the rim, should be the same as that of the teeth. The ribs, or cross-arms, should be half this thickness, and be slightly tapered towards their outer ends. The boss in small wheels should be twice the diameter of the bore; but beyond a bore of 3 or $3\frac{1}{2}$ inches this would make the metal excessive. Then this formula may be used:

$$\delta = \tfrac{1}{4}'' + \tfrac{1}{3}d.$$

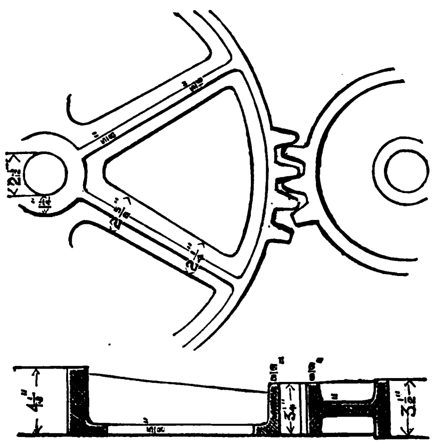
Where δ = thickness of metal in boss,
$\frac{1}{4}''$ = a constant,
d = the bore of the wheel.

The length of boss should be greater than the breadth of the wheel to ensure steadiness on the shaft, and may be obtained thus:—

$$L = B + 0{\cdot}06\ R.$$

Where L = length of boss,
B = breadth of wheel,
R = radius of wheel.

The breadth of tooth is purely arbitrary, but it frequently bears some relation to the pitch, from three to three and a half times that measurement being the commonest proportion. We



SECTION.

Fig. 8.

will plate the smaller wheel of the two with a disc having a thickness of one-fourth the breadth of tooth. Our wheels will therefore have the accompanying dimensions (Fig. 8), to which dimensions we now proceed to make the patterns.

Anyone who has had the least experience in woodworking knows how stuff which is even moderately dry will shrink and warp out of truth after having been opened out to the air. In a newly-cut surface, either desiccation or absorption of moisture will occur, depending upon the condition of the timber and the state of the atmosphere. And when wood warps, curvature in the direction of its breadth always takes place. Further, wood is only strong to resist transverse and tensile strain in the transverse section of its fibres; hence "short grain" must be avoided, as well as wide unstayed superficies in patterns. For these reasons many patterns are, in workshop parlance, "built up," and so the rim of our wheel will be built up in courses, or layers of segments. In this case the rim being 3¼ inches wide, there may be four courses of $\frac{13}{16}$ inch thick, or five courses of full ⅝ inch each. Let it be noted that the greater the number of courses, the less liable is the pattern to warp or to become disjointed by rough usage. A ring built up with a large number of these segments is like the old man's bundle of sticks in the fable.

Where the wheel is marked out in "section," take the inner and outer diameters off the drawing with a pair of beam compasses, more commonly called "trammels," and describe a template segment on a thin piece of board, allowing ¼ inch both inside and outside for turning off, and ⅛ inch at each end for jointing. In wheels of less than four or five feet in diameter let six such segments go to the circle; if larger than that, have eight or ten. Now mark out the necessary number of segments from the one thus obtained, and saw these roughly to shape with a bow, compass, or band saw. The next matter is to face up a wooden chuck true, and glue the first set of segments upon it. This first set must not be glued directly on the chuck, but to strips of paper glued, one side to the chuck, the other side to the segments. This prevents the wood from splitting away when the finished pattern is lifted from the plate, for the paper, though strong enough to retain the ring in place while being turned, splits through the middle when the pattern is lifted with a chisel.

Allow this first course of segments to become properly dry and set; then, with a turning-gouge, just skim off the rough surface of the wood. Then take a firmer-chisel, and scrape the surface smooth and level, This is most essential, as the beginner will learn when trying to joint the next course. A wooden straightedge must be chalked and passed over the surface from time to time, the projecting parts of the work being reduced as indicated by th echalk. When a straight unbroken line of chalk becomes transferred from the straightedge to the face of the ring, the surface is true, and ready for the next layer. Chalk over this faced portion, and fit to it the next course of sweeps, using a trying-plane, finely set. Plane the ends of the segments from the edge of a shooting board, or saw them with a fine tenon-saw. Glue them down, taking care, as in all glued joints, to work out all superfluous glue by rubbing and pressure combined; and have the glue newly made and rather thin. The end joints must overlap—that is, they must come one over the other alternately, like bricks in a wall (Fig. 9). The further security of the joints may be insured by fastening them either with nails or pegs, the latter mode being preferable. Nails have an unpleasant way of bending aside, and appearing just where they are not wanted. Pegs will hold as well as nails and cannot damage a sharp tool. The pegs should be *split*, not sawn, out of pine, and tapered and driven tightly into the segments through bradawl-holes bored for their reception, and they may be touched with glue to increase their adhesion.

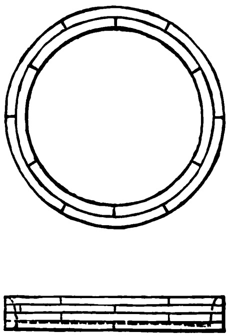


Fig. 9.

Having completed the building-up process, now turn the ring, roughing with a turning-gouge, and finishing with a firmer-chisel, diamond-point, and round-nose.

A word about these turning-tools. The multitude of tools used by amateurs and ornamental turners have no place in the pattern-maker's kit. Gouges, side-chisels, firmer-chisels, round-nosed tools, and diamond-points, each in two or three different sizes—these are all which are ever required. Beyond a plain moulding, anything artistic in the pattern-shop is seldom wanted.

The gouge used by turners is a stout tool, ranging from ¼ inch to 1¼ inch in width. The ½-inch and the ¾-inch are the most useful in general pattern-turning. In common with all turner's tools, its handle should be long, say, a couple or three inches longer than the tool itself. Much depends on the way in which it is ground. A gouge ground like Fig. 10 will do very well for quickly roughing down a long parallel surface; but for a moulding, or even for our wheel, it would be utterly unsuitable, because of the readiness with which its corners would catch in the work. What more trying to temper and patience than to see a piece of work, when all but finished, disfigured by a "kick" of the gouge at the last cut, or knocked out of truth by the force of the sudden arrest? But by grinding the gouge as shown in the second figure (Fig. 11), and holding it slightly sideways, round and hollow portions of work, and small corners, may be turned safely and quickly in half the time that would be occupied by an

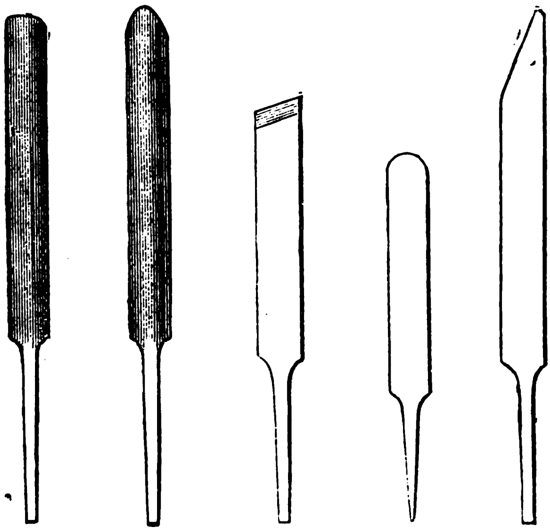


Fig. 10. Fig. 11. Fig. 12. Fig. 13. Fig. 14.

unskilful workman in *scraping* to shape with round-nose and chisel. Note also the double-bevelled obliquely-ground chisel (Fig. 12). The obliquity need not be very great. It is used as a shaping and parting tool; but it should be ground thin, and be held very firmly in the hand when in use as a shaping instrument. Gripping the handle in the right hand, place the forefinger of the left hand underneath the rest of the lathe, and clasping the tool between the last three fingers and the thumb of the same, turn, with the edge inclined at an angle with the axis of the work, cutting nearer to the obtuse than to the acute-angled end of the chisel. For work of less than 3 inches diameter, a side chisel is a clean and easily used tool; but work of larger dimensions had better be scraped with the firmer-chisel, which must be ground to a more obtuse angle than is required for common paring purposes.

For working hollow radii, the round-nose in Fig. 13 is useful either to clean and finish what the gouge has roughed out, or to work a hollow where it would be inconvenient or unsafe to attempt a gouge cut. This should also be ground somewhat obtusely. A stiff ⅝-inch coachmaker's or a mortise-chisel makes a capital round-nose, the superiority of each over a firmer-chisel consisting in their greater rigidity. For finishing holes, or for cleaning up the inner parts of small cylindrical work, where a square-ground chisel would not enter, the diamond-point or side-tool is used (Fig. 14). This is ground to any angle, but a very acute one is preferable, because it will then embrace a very wide range of holes.

All these tools should be kept sharp. It is a mistake to suppose that turning-tools do not not need so much care in this particular as bench tools. Certainly a dull instrument, which would be useless on the bench, can be made to scrape in the lathe. But no amount of scraping and glasspapering will compensate for the evil of badly sharpened tools. The time spent in keeping them in good order is more than saved by the workman.

Lastly, hold all turning-tools very firmly in the hands. A feeble or unsteady grasp will produce mischievous results, as the tyro early learns by woful experience. Wood-turning is a beautiful art, and although there is no scope in the pattern-maker's occupation for its higher developments, it should be every workman's aim to render himself an adept at the lathe, and to turn out his work with a finish that would yield credit to a professional turner.

CHAPTER III.

SPUR GEARING.

Taper in a Wheel Rim.—The use of Varnish.—Methods of making Teeth. —Working Teeth in place.—Dovetailed Teeth.—Block Templets.—Their comparative Merits.—Glasspapering.—Locking together of Wheel Arms.—Boss and Ribs.—The use of Hollows in Castings.

WE will allow the slightest possible amount of taper on the outside of our ring, where the teeth are to be fastened—not more than $\frac{1}{32}$ inch in the diameter. If we give an excessive amount of taper here, the teeth of the wheel will be working on their corners, and the stresses will be concentrated there instead of being distributed equally along the entire flanks. But on the inside of the ring we can give as much taper as we choose, without weakening the efficiency of the wheel. So there we will give $\frac{1}{4}$ inch in the diameter. The correct way to check the outside is, after having "faced" the ring, to hold a straightedge to that face, and take that as a base from which to test the accuracy of the rim by means of a set square slid against it. If the square be true, the amount by which the periphery of the wheel ring deviates from contact with it will indicate the amount of taper in the ring. The taper of the internal diameter can afterwards be measured by calipers.

The better class of patterns are varnished with shellac varnish, made by dissolving shellac in methylated spirit or in naphtha. Two or three successive layers are applied with a brush, each layer on drying being glasspapered down before the application of the next. This varnish answers two very useful purposes. To a great extent it prevents the moisture in the foundry sand from penetrating into and swelling the pattern out of proper shape; and also, by coating its surface with a smooth and glossy skin of shellac, facilitates its withdrawal from the mould, which process, in a roughly finished pattern, often breaks away or tears up the sand in patches, thereby entailing extra work upon the moulder. Therefore our ring will be varnished all over except on the periphery, where the teeth are to be fastened.

There are three principal methods of making the teeth. One is as follows:—Blocks of wood are sawn out, rather larger each way than the teeth, and glued round the periphery of the ring, the centres of the blocks coinciding with the intended centres of the teeth. When thoroughly set these are turned off flush with the faces of the ring, and to the same diameter as the points of the teeth. Sometimes wedge-shaped slips are fitted between the tooth blocks before they are turned, but a careful workman can dispense with these safeguards. The teeth are then pitched, and struck out in position on one face of the wheel (Fig. 15). A few pitch centres are then prolonged to the edge, and squared over to the other face, which is also pitched out in like manner. The teeth are worked through with gouge and chisel.

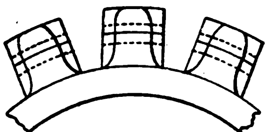


Fig. 15.

Another method is to cut a number of dovetail-shaped grooves round the ring, coincident with the intended centres of teeth, to fit dovetailed slips into these, then to glue and brad these slips on the rough blocks intended for the teeth (the slips, of course, being temporarily removed for that purpose). These blocks, then, held in position by the dovetails, are turned and marked out in position in the usual way, but being attached to the movable dovetails are afterwards readily knocked out, and worked to shape with planes, instead of with gouge and chisel. They are returned when finished to their places, and glued in finally (Fig. 16).

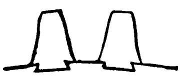


Fig. 16.

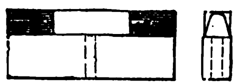


Fig. 17.

The third method is to make a block of hard wood, with one edge worked to the shape of the tooth, and notched out in the middle to just its required length and width. Into this templet the blocks intended for the teeth are driven and there planed to shape, the plane being guided accurately by the contour of the hard wood (Fig. 17). These teeth are then set to the centres pitched out on the ring, either by one of their edges or by a centre line marked on each of their ends, and while the glue is still wet they are adjusted more minutely by means of calipers and square.

Another method useful where only a few teeth are required, as for a pinion of from ten to twenty cogs, is the following (Fig. 18):—Get a piece of wood long enough to embrace the radius of the pinion, strike a single tooth upon it near one end, with the necessary centres, then cut out a notch sufficiently wide to embrace the root of the tooth. Plane the stuff intended for the teeth quite parallel to the width of this notch, square one edge, and cut to length. Drop each end of each tooth block in succession into the notch in the board, and mark out. The rigidity of the centres will ensure their being all marked alike, and they can be worked to shape with planes.

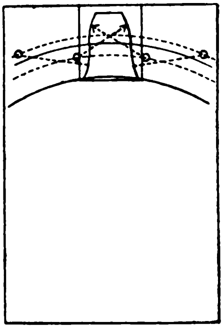


Fig. 18.

Of these four methods, the first is very accurate, owing to the teeth being pitched out in place; but there is the serious disadvantage involved in the use of gouge and chisel instead of the plane. Very much time is occupied, and in the hands of a clumsy workman the teeth will become hollowed and rounded, and will show angularites which will interfere more or less with their easy moulding and their even working. The second system is undoubtedly the best, as it combines complete precision in marking out with perfect accuracy in shaping, and the time occupied in dovetailing is saved, or very nearly saved, in the operation of working to shape with the plane instead of with the gouge and chisel. Still, it is an expensive method, and except in the case of wheels requiring great perfection, or in standard patterns which are to be constantly in use, is an unnecessary expense. The third and fourth plans are the cheapest, and are sufficiently good for ordinary work. The teeth having been worked in the block, are, as before mentioned, glued on the centre lines marked across the rim of the wheel, and checked with square and calipers before the glue is set. The square is tried along the flanks of the teeth, to see that they are at right-angles with the faces of the wheel, and the calipers are tried across from one tooth to its next fellow on the pitch-line, to insure uniformity in their pitch throughout. When the teeth are set firmly, clear away the superfluous glue with a chisel; secure them permanently by driving a couple of brads through each into the rim; punch in the heads of the brads, and fill up their heads with a mixture of chalk and shellac-varnish, or of putty. Then proceed to glasspaper. This requires to be carefully done. Make a rubber shaped on one side like that portion of the flank of the tooth below pitch-line, but the reverse way, and let the other side be flat. Laying the glasspaper on this, rub the flanks across the grain, and take care that the rubber beds firmly against the teeth whilst in use, else the glasspaper will injure their shape by making them rounding. The teeth should be tapered slightly for delivery, but so slightly that bearing a trifle harder on the down side than on the top with the glasspaper will make sufficient taper in a shallow wheel. In a deep wheel the teeth should be marked out a little larger on the top than on the bottom side, only, however, by the thickness of two or three shavings. When glasspapered, apply varnish, rubbing down each coating before applying its successor.

Now take the arms. Plane up three strips of wood, each as long as the diameter of the wheel, as thick as the arms are intended to be, and wide enough to include the radii by which they curve into the rim. Next set a bevel to 60°, and with this bevel laid against the edge of one of the strips, describe two lines the width of a strip apart, and equidistant from the centre of the piece. Divide the thickness into three parts, and gauge and cut out two such parts from the central space included between the bevelled lines just marked. This recess may be roughed out with a paring-gouge and chisel, and finished with a rebate-plane (Fig. 19, A). Now take the second of the three strips, mark two bevelled lines as before, but gauge and cut out one-third only of the thickness of the strips (Fig. 19, B). Drop the two pieces together, and they will be flush top and bottom. Take the third piece, and mark four instead of two bevelled lines upon it, crossing one another, which lines will of course meet in the longitudinal centre of the strip. Gauge and cut out two-thirds thickness between these lines (Fig. 19, C), it will then drop over the edges of the other two pieces. Place this arm in position, and mark two lines coincident with its edges upon the two arms previously locked together. Then cut away the wood between these two lines (Fig. 19, D and E, E) a third deep, and drop piece c in place. On the stuff thus framed together now mark out the six arms (Fig. 20), take apart and work, and glue

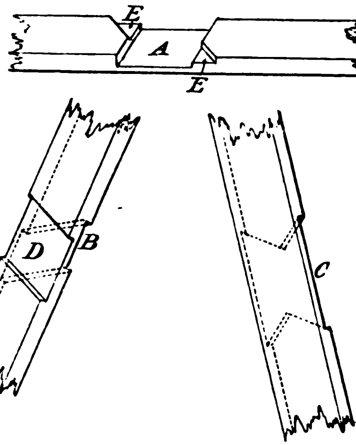


Fig. 19.

together finally, then let into rim. Cut the ends of the arms, say, ½ inch shorter than the diameter of the rim; lay them

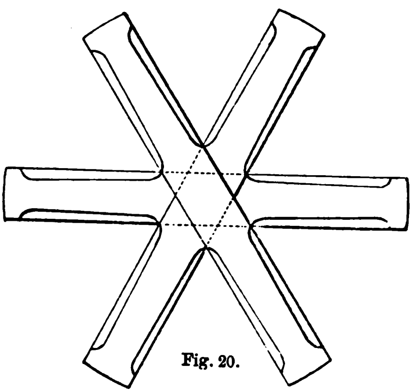


Fig. 20.

on the back of the wheel, and mark, from their ends and adjacent sides, half-a-dozen recesses on the rim, to be cut out to a depth equalling the thickness of the arms. Into these they will be dropped, glued, and screwed.

Now turn a boss for the wheel-centre, and screw it in place, Fit the half-dozen ribs between the boss and the interior of the rim, screwing them through the arms from the back. Or these ribs may be locked together similarly to the arms, and the boss fitted over and between them. This would give greater rigidity to the wheel-centre.

Our wheel might now be considered finished but for one little matter, which is of more importance than it might seem at first sight. A good engineer will always endeavour to avoid sharp corners, therefore it is customary to put what are termed "hollows" in the best patterns. These are strips of wood worked out to the annexed section. Where they are not actually put in the pattern, the moulder cuts them in the sand with a special tool.

The reason why sharp corners are avoided is this:—Cast-iron always crystallises at right-angles to the surface against which it is cooled. Hence a ring will be the strongest form of casting, because the crystals will all radiate symmetrically (Fig. 21). But take a right-angled figure (Fig. 22): obviously there will be a break of the crystals just in the

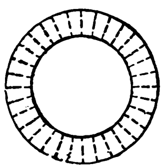


Fig. 21.

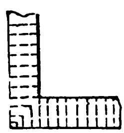


Fig. 22.

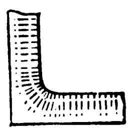


Fig. 23.

angle of the casting, forming a permanent source of weakness. Invariably, other conditions being equal, the casting will give way here before anywhere else. Put a hollow, however, in the angle, and the crystals will form without any line of separation (Fig. 23).

For this reason many of the best wheels are made with hollows at the roots of the teeth, for here the action of leverage on the tooth induces the greatest stress. And it should be laid down as a rule that sharp corners in all castings subject to much stress should be avoided. In the case of a wheel, we shall put the hollows in the pattern. Plane up some strips of wood, say $\frac{3}{4}$ inch square and two or three feet long, lay them on an angle-board, and with a round plane, about No. 10, hollow them out in a diagonal direction, then cut them off to required lengths, and glue and brad in position.

All that now remains to be done is to fill up all screw and brad-holes with a mixture of chalk and varnish, or putty; glasspaper and varnish; put on a core-print in the centre of the boss on the down side, and a rapping plate or two on the top side of the pattern.

CHAPTER IV.

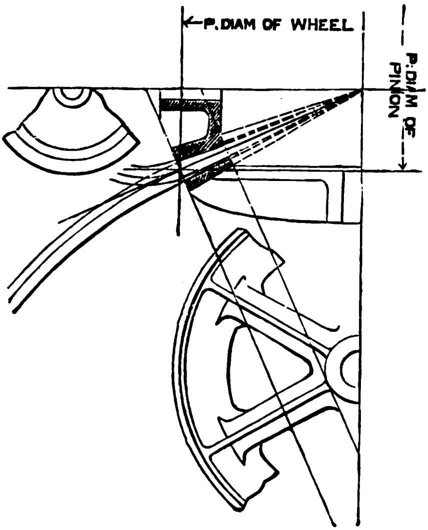
BEVEL WHEELS.

Principle of Bevel-wheels.—Mode of striking out.—Wheels in Section. —Projection of Teeth.—Building-up of the Rim.—Turning with Templets.—Getting Centres for the Teeth.

THE making of a bevel-wheel involves the exercise of rather more skill than the making of a spur-wheel. In the case of the former there are two diameters, a larger and outer, and a smaller and inner diameter. The pitch and pitch diameters are reckoned on the outer or larger diameters of these wheels. The size of the inner or smaller diameter, and the pitch-centres on that diameter, will be controlled entirely by the breadth of the wheel, a wide tooth manifestly making the inner circle smaller than a narrow tooth would do. The same remark of course applies to mitre-wheels, which are simply bevels of equal diameter set at an angle of 90°. The one essential point to remember in these wheels is that all lines representing tooth-flanks, thicknesses, lengths of radii for striking curves of teeth, &c., *converge to the common centre of the wheels.*

For the working drawing we strike out a sectional view (Fig. 24). Mark the pitch-diameters on the drawing-board at right-angles with each other if the wheels are to work at right-angles; at the proper bevel if at any other angle. Where the axes of these pitch-diameters intersect will be the common centre of the wheels towards which the lines converge. Project, therefore, these pitch-lines to the common centre; upon them mark off the breadth of the tooth, and there draw a line at right-angles to the pitch-line. Now measure off the distances above and below pitch-line on the larger diameter of wheel, thence draw lines towards the centre as far as the inner diameter of the teeth. The distance between these lines there projected will represent the length of the tooth on the small diameter. In like manner, indicate the *thickness* of the tooth on the outer circle; that dimension similarly projected will give its thickness on the inner circle. And when afterwards the radii are found by which the flanks of the teeth are to be struck, the lengths of these radii projected to the inner circle will be those used for striking the small ends of the teeth.

A word about the projection of the teeth to a plane surface. Manifestly the pitch-diameter of a bevel-wheel will not show the teeth on a flat surface. Looking at such a wheel in plan (Fig. 25), the faces of the teeth will not form a right-angle with the eye, but some other angle dependent on the



Figs. 24 and 25.

obliquity of the wheel-teeth. The correct method, therefore, to strike out the teeth is as follows:—

Project the line which represents the axis of the wheel to a considerable distance outwards, then draw a line at right-angles with the pitch-line, and coincident with the outside faces of the teeth, prolonging it until it cuts the projected centre-line. The distance from this intersection to the pitch-line on the outer diameter will give the projected radius of the larger diameter of the wheel. The same method adopted in the case of the smaller diameter will give the proper radius for that also. On the arcs struck by these radii use rolling circles exactly as in a spur-wheel. The same rules also will apply to the general proportions of bevel as to those of spur-wheels.

Having struck out our wheels in section, the next care will be to build up the ring. Evidently the segments of which it is composed will not be built vertically one above another. They will overlap as shown in sketch (Fig. 26), and should be pencilled in that position on the sectional drawing to guide the workman when sawing out. The ring being built up, according to the instructions given in Chapter II., the turning becomes a matter requiring care. In this case we must make templets (Fig. 27). We shall turn the outer face on which the teeth are to be fastened first. Face the wheel and strike the diameter A first, taking it with compass or trammel from the board. Make templet B by the board also; then putting a straightedge across the level face, turn the outer bevel of the rim until the templet is coincident with the face of the straightedge on one edge and with the bevelled wheel face

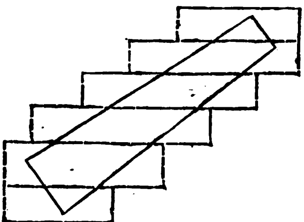


Fig. 26.

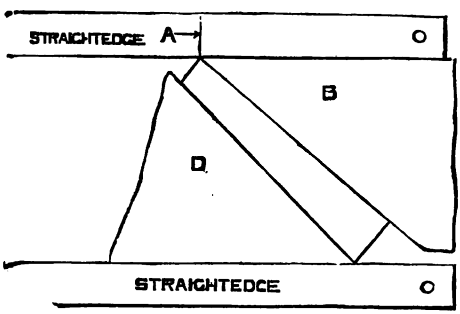


Fig. 27.

on the other, as shown in diagram. Then turn the narrow edges with a bevel set to their respective angles. If it is intended that the teeth shall be turned and pitched out in position, they should be glued on at this stage, before the ring is taken off the chuck; but if not, it will now require to be chucked for the purpose of turning the other side. This will be done by running a shallow groove, say ⅛ inch deep, in the face-plate, into which the portion of the rim marked A will fit, and screwing the rim into this groove from the back of the plate. The back, or inner face, will then be turned with straightedge and templet, as indicated at D. Here the advantage of pegs over brads will be apparent, for they will come through the bevelled segments everywhere, without being detrimental to the tool edges.

The arms may now be locked together, as in the spur-wheel pattern; but we shall not be able to recess the ring for their reception, so must simply fit them to its internal diameter, and secure with glue and screws. The hollow sweeps coming into the angles, being fitted afterwards, will give them additional support. The boss and the cross ribs will be made also as in a spur-wheel; but it will be more favourable for moulding if they are left loosely dowelled on the arms, instead of being screwed permanently. The reason is that while in the spur-wheel the ribs are downward in the mould, in the bevel-wheel they are uppermost, in order that the teeth, where the soundest metal is wanted, shall be cast downwards.

Fastening the teeth on the rim is a trifle more difficult than in the case of a spur-wheel, because the square cannot be brought into requisition. Proceed as follows:—Having pitched the outer circumference of the wheel for the proposed number of teeth, raise a perpendicular line with compasses as shown in diagram (Fig. 28). This being normal to the circumference will be radial with the centre, and as the teeth converge to the centre will be a starting-point from which to pitch out the inner circumference. Four or five of these perpendiculars should be raised at regular intervals, so that the liability to error in marking out may be reduced to a minimum, and almost neutralised by taking the average of the whole series. The inner circumference pitched out, it only remains to work the teeth in a block, to mark centre lines upon their ends, glue and secure them in place, clean and varnish.

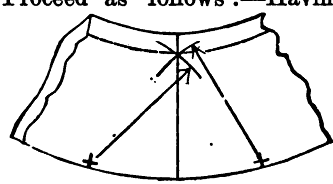


Fig. 28.

CHAPTER V.

WORMS AND WORM-WHEELS.

How to strike out.—With Circles.—With the Odontograph.—Pattern of Worm.—Templet of Diagonal Lines.—Mode of cutting Worm.—Building the Wheel.—Jointing.—The Teeth.

It is not an easy task to make wheels of this class so that there shall be continuous contact between the teeth in every portion of their flanks in succession. Comparatively few are found to fulfil this condition, most worm-wheels touching only round their central portion. But continuous contact is not of so much importance in these as in spur-wheels, for almost any worm-wheel will work smoothly, simply because there are several points of contact between the worm and its wheel in gear simultaneously, while in spur-wheels we have seldom more than two, frequently only one tooth, in actual gear all the time.

To strike out a worm and its wheel proceed thus. We require, we suppose, a worm-wheel of 12-inch pitch-diameter, of 25 teeth, by 2 inches wide, to be driven by a worm of 3-inch diameter. The pitch will be 1½ inch. Draw then a straight line 9⅜ inches long (the circumference of 3 inches), 1½ inch out of perpendicular (Fig 29). This will represent the bevel of the wheel-teeth, and a length of 2 inches measured on this line will give the amount of inclination of the centre lines of these teeth. Draw out the teeth in section. Two sections of the pair must be drawn, one horizontal (Fig. 30), cutting the teeth across the centre, the other vertical, taking them lengthwise (Fig. 31). The teeth in the horizontal section will be struck out as in an ordinary wheel and rack, the worm itself answering to the rack in this respect, that the base-line for the generating circle will be straight instead of curved, and if struck with the odontograph scale the slant edges will be placed against lines drawn at *right angles* with the pitch-line.

The outline of the vertical section will be decided by the diameter of the worm. Strike the 3-inch pitch-circle from the worm-centre—that circle will also give the proper vertical curve to the pitch-line of the worm-wheel. Set off the depths of the teeth above and below pitch-line, as explained in Chapter II., and strike the lines representing these, both in wheel and worm, from the worm-centre.

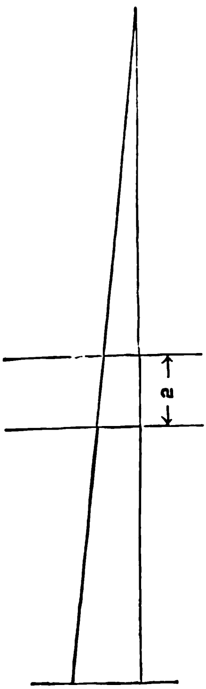


Fig. 29.

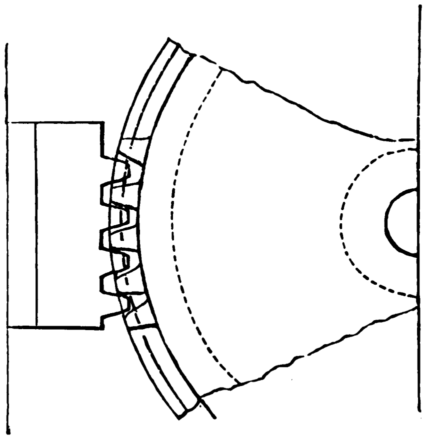


Fig. 30.

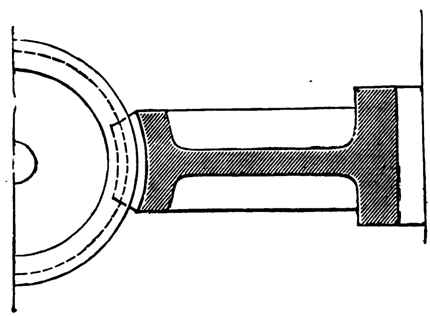


Fig. 31.

Making the pattern of the worm first, joint two pieces of stuff together with dowells, of such a size that when turned with the joint exactly in the centre they will hold up to the diameter of the points of the thread. Secure them while in the lathe, either with a screw at each end (see page 160) or by a couple of the centre-plates which are in common use in pattern-shops. Now turn to the required size in diameter and length, not forgetting the prints at the ends, which in this case will not require taper at all, because they will not mould vertically, but in a horizontal plane.

There are two methods of marking out a screw or worm upon the plain turned body; one—of which we will speak when we come to talk about large screws—is by the projection of equally divided lines; the other is by means of a number of diagonal lines marked on paper, and fastened round the

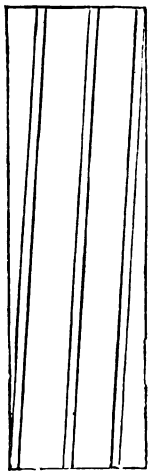


Fig. 32.

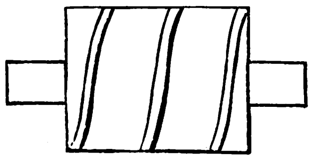


Fig. 33.

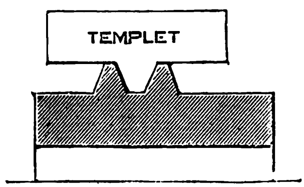


Fig. 34.

wood to be cut out screw-shape. This latter is the one we will adopt for our worm, as being readier of application in so small a pattern.

The diameter of the worm outside the teeth is $4\frac{1}{8}$ inches; its length, say, $4\frac{1}{2}$ inches. Get a piece of paper $13 \times 4\frac{1}{2}$ = circumference and length; on this mark diagonal lines $1\frac{1}{2}$ inch out of perpendicular and $1\frac{1}{2}$ inch apart = the pitch of the worm. Then another set of diagonals parallel with these, and at a distance from them equal to the thickness of the teeth at the point (Fig. 32). Glue this paper round the periphery of the turned block, and the inclined planes will develop the outline of the worm (Fig. 33). It only remains to make a templet fitting between the teeth we have marked on the board, and to use this templet as our guide in working out the space between the screw points (Fig. 34). That portion of the templet which corresponds with the points of the spiral must be kept parallel with the points in working, since, if it is suffered to slope, the shape of the tooth will be affected thereby, and we shall get it unsymmetrical. It is best worked in the lathe between centres, the inter-tooth space being cut away with saw, chisel, and paring-gouge.

The wheel will be built up in the usual way, but it must be made in two halves, parted horizontally, and dowelled together. The reason of this is obvious. A pattern with projecting edges could not be drawn from the sand, therefore we must make it in two parts, jointed in the narrowest portion of the diameter. The moulder then uses a three-parted box, so that while the two end faces of the teeth are in the top and the bottom boxes, the teeth themselves are contained in a middle ring of sand.

The worm-wheel being rather small, a plated centre will be more suitable than arms. It is not advisable to make the centre plate of solid stuff, which will almost certainly shrink in the course of time. It should be built up in at least two thicknesses of segments for each half. Or the plate might be built up to its entire thickness, and the ring only be parted

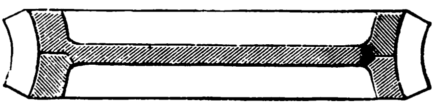


Fig. 35.

through the centre, the shouldered portion acting as a dowel to keep the two halves steady in the mould (Fig. 35). Or the plate might be made of one thickness of stuff with "open joints"—that is, joints $\frac{1}{16}$ inch or $\frac{1}{8}$ inch open, to allow of the partial swelling of the pattern in the sand without affecting its proper diameter. The rings are glued up in segments, each on separate face chucks, and jointed before their peripheries are turned. The edges of the two halves of the wheel must be turned by templet, marked from the sectional drawing (Fig. 31), and the teeth must be fitted and glued on in rough blocks, then turned to outline by templet and worked to shape afterwards. They must be struck on the two outer faces and in the joint; the pitch on the outer faces, of course, will not be the actual pitch of the wheel, but the larger diameter will be divided equally between the number of teeth. Work them with gouge and chisel, using a templet, and trying the worm round from time to time. The getting the correct shape on the outer faces is difficult, though quite practicable; but the best way is to put the worm in the lathe, red lead it, and cut the worm-wheel teeth until the lead shows contact everywhere. They must be glasspapered by hand, the use of a rubber not being practicable.

CHAPTER VI.

MACHINE-MOULDED WHEELS.

The Change effected by the Introduction of Wheel Machines.—Parts necessary for Machine use.—The Teeth.—How moulded.—H-shaped Arm Cores.—Form of Core-box.—Bevel-wheels.—Striking Boards. —Top.—Bottom.—Arm Core-box.—Disc or Plate Wheels.

Of late years the use of wheel castings made by a moulding machine has become very common. The writer often mentally contrasts the revolution which the wheel machines have effected in this particular section of workshop practice, as he remembers what makeshifts were resorted to in order to economise the pattern-maker's time before the wheel machines were introduced. Wheel patterns are expensive to make, and, once made, they were used over and over again, and that even for jobs for which they were not wholly suitable, and for which a new machine-made wheel would now be ordered. Wheels were "drawn," "stopped-off," lined, and thickened up in various ways. And where a new one was absolutely necessary, the rim would be made in cores—about half-a-dozen teeth in a box, and the arms in a core-box also, or sometimes by a single arm, or a couple of arms "bedded in." All these makeshifts are now abolished, in the larger shops at least, by the introduction of the wheel machines, and the smaller shops find it cheaper to buy their wheels of the firms who make them a speciality rather than turn out inaccurate castings by the old roundabout processes. For the new wheels have the double advantage of accuracy as well as cheapness, since if the machine parts are kept in good order, and no "slop" exists, each tooth will be an exact counterpart of its fellow. The use of these wheels has become so general that while engaged on the subject of gearing something ought to be said about the essential parts which the pattern-maker has to prepare for machine use. For plain spur-wheels they are—block (Fig. 36), core-box (Fig. 37), diameter-strip, and finger-bit.

The block is made of a piece of pine or mahogany, equal to the depth of the wheel rim, and of a convenient length and width

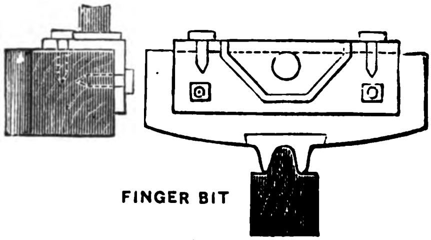


Fig. 36.

for the carrier of the machine; say 10 inches long by 4 inches wide. The outside edge of the block is worked to the same radius as the rim of the wheel which is to be made. The

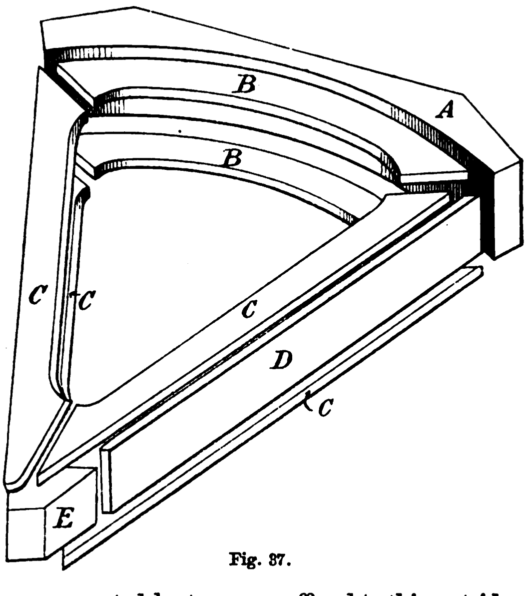


Fig. 37.

teeth are represented by two cogs affixed to this outside sweep, of the desired shape, size, and pitch (Fig. 36), and the moulding proceeds as follows:—

The tooth-block is screwed to the carrier attached to the arm of the machine. Its distance from the centre of the machine—equal to the radius of the wheel—is given by a strip of wood, the diameter-strip, which reaches from the central pillar to some part of the tooth—either root or point. The proper change wheels being put on, the *space between* the two teeth is rammed up with sand, and the block is then lifted out of the mould by means of the hand-wheel actuating the vertical arm to which the carrier is attached. The sand is prevented from coming up with the block by a thin piece of wood—finger or hold-down bit—cut out to the same shape as the space between the teeth, and kept pressed on the included sand during the process of withdrawal of the block. When the block is clear of the sand, the requisite number of turns is given to the slewing-handle to carry it round a distance equal to the pitch, when the process of ramming up and withdrawal is again repeated. In order that the tooth block when in the act of being lowered shall not scrape away the sand already rammed to shape, the outer flanks of the teeth are reduced below the correct size. This, of course, is not detrimental tothe form of the moulded teeth, the space alone *between* those on the block being used by the moulder. Each time the block is moved another tooth interval is rammed up, until the ring is complete. If the block is properly made, and the sand rammed sufficiently hard, and sprigged, the mould will not tear up at all, notwithstanding that the teeth are without taper, but will be ready for blacking at once.

The arms of machine-moulded wheels are made with cores, for which a special box will be necessary. They are usually H-shaped in cross section. To make the core-box (Fig. 37), in which the parts are represented as drawn slightly apart for the sake of clearness of illustration, the pieces necessary are a sweep, A, representing the inner portion of the rim, and as long as the space included between two contiguous arms—a fourth, sixth, or eighth part of a circle as the case may be; two sweeps fitting within this, B, B, one top, the other bottom, which are the ribs or flanges strengthening the rim; four half-width arms, C, C, fitting with the ribs and with each other; two half cross ribs, D, and a boss piece, E. These pieces are all rammed up loosely, that is, the parts are merely abutted, not screwed together, and taken from the sand one by one. They are rammed in an outer frame—not shown—consisting of two pieces screwed at the requisite angles, and of the same depth as the wheel. If there are four arms, the core-box will be made at the angle of 90°; if six, of 60°; if eight, of 45°. Sometimes an outer frame of iron is used as a permanent core-box for any sized wheel. Where that is the case the loose pieces only will be wanted.

These cores, either green or dried, usually green, are placed in position in the space included by the ring of teeth; a centre core for the wheel shaft is then fixed by measurement, completing the mould for a plain wheel.

With bevel-wheels the process is not exactly the same. Here striking-boards are necessary. They are two in number, one for striking out the bed for the arms and the points of the teeth, the other for the top portions of the wheel. The

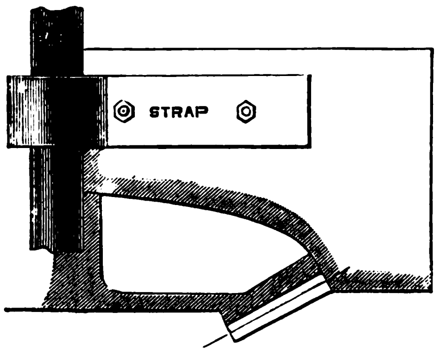


Fig. 38.

boards are screwed to a bar forming a continuation of a socket which fits over and turns round the central post. The striking edge is chamfered similarly to that of a loam board.

The moulder proceeds thus with the top board, which being for green sand, as is commonly the case, is cut the reverse way to one intended for a loam mould, as shown in sketch (Fig. 38).* He strikes over a bed of hard rammed sand representing the top of the boss, the edges of the vertical arms and of the rim, and the outer or larger faces of the teeth, finishing off in a horizontal direction at their points to form the joint of the mould. A moulding-box or flask large enough to cover the bed thus struck, is set in position and rammed up on it—a layer of parting sand alone intervening. This is the top of the wheel mould, which is

* See also Chapter XXX., p. 225, for the difference between boards for loam and greensand.

now removed. The sand in the temporary bed is now dug away for the purpose of striking the lower part of the mould. The bottom board (Fig. 39) is set in position by means of the horizontal joint of sand already made, and strikes the flat faces of the arms, the inner edge of the rim, the smaller faces of the teeth, and their points. The tooth block is then screwed on the carrier of the machine, and the moulding proceeds as in a spur-wheel, with the exception that no finger-bit is required. The arm-cores are also made and set in the mould in a similar way. For bevel-wheels, however, the arms are of the same shape as those in an ordinary pattern, so that the remarks we have made about H arms will not apply here. The outer sweep of the core-box represents the inner side of the rim, and the way to make it can be seen by a glance at the sketch (Fig. 40), where the rectangular figure represents the rough block from which the bevelled inner portion of the rim, shown shaded, is cut. The top of the cores being curved, must be worked off by means of a strickle, similar in shape to the top board, Fig. 38.

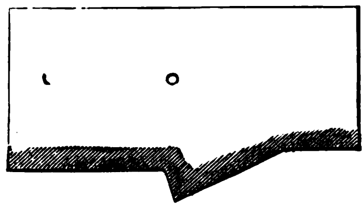


Fig. 39.

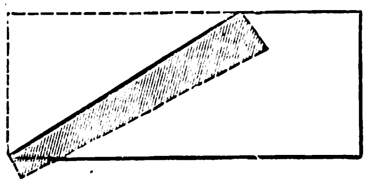


Fig. 40.

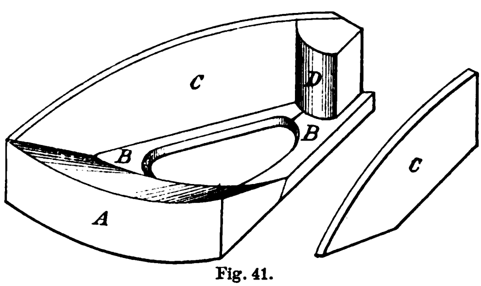


Fig. 41.

So that we require sweep (Fig. 41, A), two half arms, B, B, two half ribs, C, C—that is, each rib of half the casting thickness—

boss, D, loose for withdrawal as before, and strickle. A look at the sketch (Fig. 42) will also indicate the shape and mode of cutting out of the tooth block, the shaded portion merely indicating the rim section in relation to the block, while the

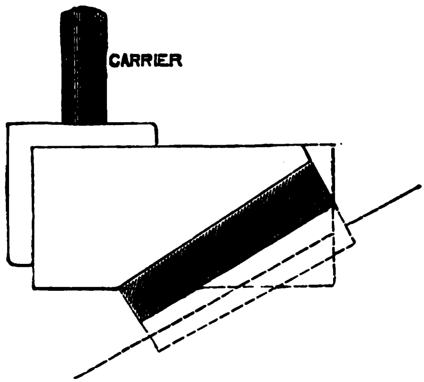


Fig. 42.

teeth differ in nowise from those of an ordinary bevel-wheel. Fig. 43 represents the mould of a bevel-wheel in section.

Sometimes in the case of a small wheel arms are not used,

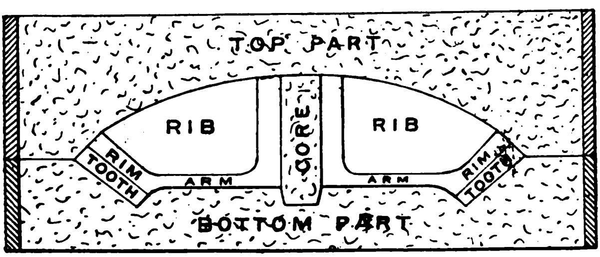


Fig. 43.

the wheel centre being simply a disc or thin solid plate. Here the top board would strike the outline of the inner portion of the rim and the back part of the disc, and cores would not be wanted at all.

CHAPTER VII.

MORTISE-WHEELS, &c.

Mortise-wheels.—Why used.—Metal in Rim.—Thickness of Cogs.—Taper in Mortices.—Prints and Cores.—Wood used in Gearing.—Sawing Cogs.—Driving.—Fastening.—Splitting of Wheels.—Shrouding.—Breaking Strength.—Basis of Calculations.—Ratios of Wheels.

MORTISE-wheels are those which are geared with wooden cogs, instead of with iron teeth. In a large mill or factory where many pairs of wheels are constantly at work, and running at high speeds, the noise and the shock would be unendurable if iron-toothed wheels alone were used. To prevent this nuisance, wheels with wooden cogs are made to gear with iron fellows. They answer admirably, but are very expensive, involving not only the cost of the wooden teeth, in addition to the casting, but the chipping and filing to a smooth surface of the flanks of the iron teeth (scarcely necessary, though, in the case of machine-moulded wheels), without which precaution the wooden teeth would become rapidly abraded.

In making the mortise-wheel pattern, proceed generally as for an iron wheel. But bear in mind that the thickness of the rim here should be equal, not to the thickness of the teeth, but to their *pitch*—a deep mortise being essential to the steadiness of the tooth-shank. Also that a thickness of metal must be left beyond the ends of the shank, equal to about four-tenths of the pitch. The cogs, moreover, are a third thicker than those of the iron wheel into which they work, and *no clearance* is allowed between the two. Core-prints must be used for the mortises, whether the wheel be made by pattern or by machine, and a core-box containing the requisite amount of taper must be made. The taper given to these mortise cores should not be more than $\frac{1}{8}$ inch on a side for each $1\frac{1}{2}$ inch of depth, for if it becomes excessive the teeth will have a tendency to spring when being driven into their places, and so, possibly, by setting up too much vibration in the wheel the rim will become broken. And further, largely tapered teeth will work loose earlier than those tapered to only a moderate extent. In a spur-wheel the prints will come to the top edge of the rim (Fig. 44), and the portions of the prints which reach above the mortises will be "stopped" up after the cores are placed in. The best way is to make the core-box to "stop itself off"*—that is, to take out the mortise and fill up the entire print besides. Fig. 45 represents a

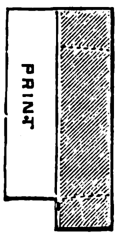


Fig. 44.

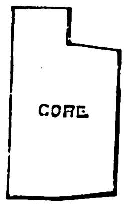


Fig. 45.

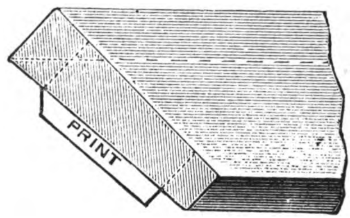


Fig. 46.

core thus made. In a mortised bevel it is not necessary that the prints should come to the top edge; but their upper ends must be chamfered off, so that they may not drag the mould (Fig. 46). The core-box will be made to correspond.

Having the wheel castings, next comes the fitting in of the teeth, or the "gearing it," as it is termed. This was formerly a speciality of the millwright, but now the pattern-maker looks upon it as his legitimate work. We suppose, then, that the rim, both on face and edges, has been turned, as in good work it should be, and delivered into the pattern-maker's hands to be geared. First, regarding the selection of the wood for that purpose. Hornbeam, apple-tree, oak, acacia, beech, are commonly used. On the whole, I think apple-tree carries the palm; but hornbeam, beech, and oak are also very good. One essential is that the wood be the driest procurable. Unless the mortise wheel is to go into a damp situation, as in the pit of a mill-wheel, its teeth are certain to shrink in time, and the rattling of a number of wooden cogs in their sockets is quite as intolerable as the rattle of iron and iron wheels would be.

Saw the blocks out so that the points of the teeth shall cut

* See Chapter VIII., on Core Prints, p. 53.

across the *end* grain, that is, the grain fibres will radiate from the centre of the wheel; let them be cut of such a length that their shanks shall project about an inch from the inside of the rim, and leave also sufficient allowance on their faces and points for turning. Shank them with a hand saw, using a templet to insure uniformity throughout, and leave a little, say $\frac{1}{32}$, on each side for accurate fitting with a rebate plane. If a circular saw is available, the labour of handsawing may be avoided by making a block or carrier to slide along the saw bench, holding the tooth in it in such a position that the shoulder of the shank shall coincide with the *top of the teeth* of the saw. Or in shops where a general joiner is kept the tenoning apparatus may be utilised.

Fit the teeth in carefully, driving them tightly with a fitter's hammer or a light sledge, until their shoulders are within $\frac{1}{4}$ inch of the rim. With a pair of compasses scribe the shoulders of the shank or tenon parallel with the rim, then knock out and cut with a chisel to those scribed lines. Get some oil paint, thickly smear it over the tenon, and drive the tooth block finally home. There is some knack required in driving these cogs, for though they will bear, and indeed ought to have, hard driving, yet it is possible just to exceed the limit, and to burst the rim of the wheel. The ends just past the tenon are also apt to fly off with the final blows. To prevent this they must not be undercut, and the strokes should be given just over the shank, not *beyond* it, and should be dead and firm, not elastic in character.

The teeth, although fitted carefully and driven home firmly, would yet work loose in time if no further support were afforded them. One mode of securing is to drill holes through the metal at the ends of the mortise, and to drive wood screws or pins through these into the tenon (Fig. 47). This is strong and neat, but it requires a large amount of drilling. Another way is to cut out dovetailed grooves in that portion of the tenons projecting inside the rim, and to drive in wooden wedges between the contiguous teeth (Fig. 48). This also has the merit of security, but necessitates labour which is superfluous.

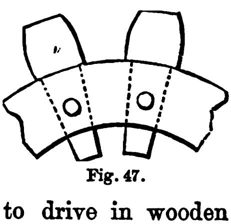


Fig. 47.

A third method is to prepare a number of wedges of sheet iron or steel not more than $\frac{1}{8}$ inch thick, and about $\frac{3}{16}$ inch wider than the space between the shanks. Their edges must be ground sharp and bevelled, and they are then driven tightly between the shanks (Fig. 49). But the same end may be accomplished by a fourth method simpler than the other three. Bore holes at the ends of the tenons within the rim, but close

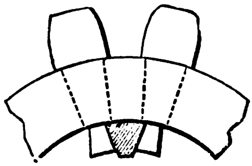


Fig. 48.

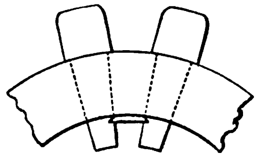


Fig. 49.

against it. Drive pins, which may be either lengths of pointed wire, about ⅛ inch in diameter, or clout nails with the heads cut off, into these holes, allowing about ½ inch of pin to stand out from the wood (Fig. 50). This is as firm

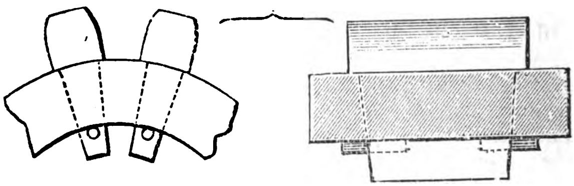


Fig. 50.

and lasting as any other fixing, and has the merit besides of being expeditious.

Having secured the cogs, the wheel must now be put in the lathe again, and their faces and points be turned. The pitch-lines and the striking lines for the radii of the tooth flanks are to be run round, and the teeth divided and marked out, and cut through with gouge, chisel, and straightedge. They are not glasspapered, but simply wiped over with oil. The wheel is then fit to be put in its place.

A few remarks of a general character, having reference to the subject of gearing, may fitly close this chapter.

Splitting of Wheels.—This means the casting of a wheel in halves, necessary when, from its intended position in the middle of a shaft, or between other wheels, it could not be driven on endways in the usual method. Being made in two, provision must be given for securing the parts together when in place. This is done by casting lugs or ears on opposite sides of the boss, and in corresponding positions within the rim. Holes are cast through these to receive the bolts (Fig. 51). Sometimes—and this is the neatest way—the

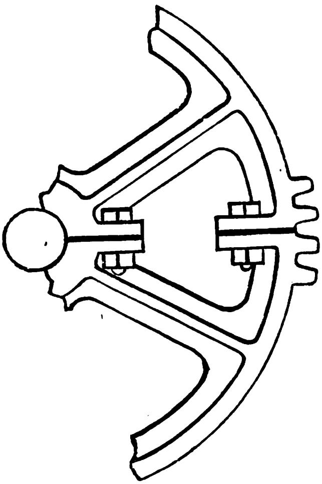


Fig. 51.

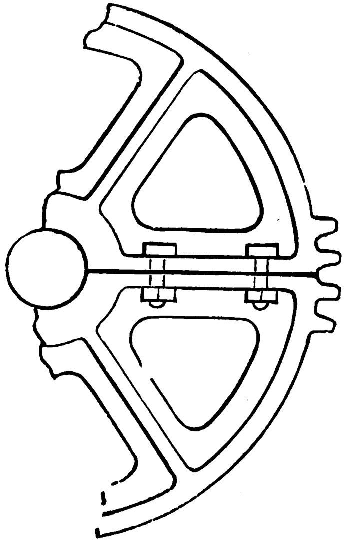


Fig. 52.

wheel is split through the centre of an arm. In small castings this has a less unsightly appearance than the lugs. Each half arm, however, must be made of the same width and thickness as an entire arm, else the splitting would become a source of weakness (Fig. 52).

The details of the process of splitting are the same, both in pattern and machine wheels. Make the lugs and fasten them

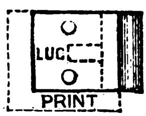


Fig. 53.

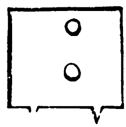


Fig. 54.

on each side of a core print, sufficiently deep and wide to support the core in a vertical direction, and of the proper thickness—from $\frac{1}{4}$ inch in small wheels to $\frac{1}{2}$ inch in large ones (Fig. 53). Secure these lugs in position. Then make a templet of the splitting plate for the moulder, following both the outline of the print and also that of the portion of the wheel it is intended to split. Cut in it holes of the intended size for the bolts, and in the proper centres. From this templet wrought or cast iron plates will be made. They will then be covered over on each side with a thickness of loam or of tar, and will be dried. Round cores of the same length as the thickness of the double lugs will be thrust through the holes, projecting equally from each side to form the bolt-holes in the casting. These plates thus prepared (Fig. 54) will be dropped into the prints dividing the lugs, and will part the casting in two.

Shrouding.—This term, as applied to wheel gearing, signifies the supporting of the teeth at their faces with a flange or annular ring, and may be either half or whole shrouding, according as it extends to the pitch-line (Fig. 55),

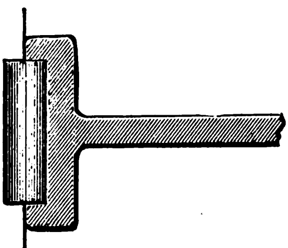


Fig. 55.

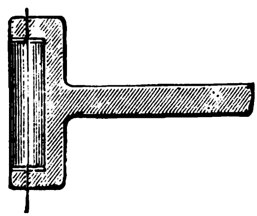


Fig. 56.

or to the points of the teeth (Fig. 56). It is of especial value in small pinions having weak roots, and is commonly believed to increase their strength by 40 to 50 per cent.

When the shroud comes in the bottom of the mould, it is essential that it be left loose from the body of the pattern, being simply dowelled on to prevent it from becoming rammed away from its proper position. In the top of a mould it is also desirable that it should be left loose, though not so absolutely necessary. In the case of a machine-made wheel, shrouds will be struck by the boards, and the broken edges of the mould will be mended up afterwards, with a sweep similar in section to the shroud. *See* Chap. XXX., p. 225.

Breaking Strength of Teeth.—A wheel-tooth must be regarded as a loaded beam or cantilever, its length being the distance from root to point, its depth the thickness of the root at its base, its breadth the breadth of the wheel.

To ascertain the strength of a cantilever the rule is: "Square the depth, multiply by the breadth and strength of material, and divide by the length." A cantilever of good cast iron, 1 inch square and 1 inch long, will sustain a dead load of 6,000 lbs. before it breaks. Applying this to the tooth of a wheel of $1\frac{1}{4}$ inch pitch, $3\frac{1}{2}$ inches on face (Fig. 57), we find that it will sustain a dead load of—

$$\frac{1\frac{1}{8}^2 \times 3\frac{1}{2} \times 6000}{1\frac{1}{4}} = 22212 \text{ lbs.}$$

before breaking. Dividing this by a factor of safety, say 10, (it should be large for gearing), we get 20 cwts. nearly, as a perfectly safe load for such a tooth.*

But it is usually assumed that two teeth are always in gear at once, which assumption would, if correct, double the effective value of our calculation. And it is quite true of a pair of large wheels not very disproportionate in relative diameter, and properly marked out. Two teeth are always in gear at the same time, and sometimes three; but in a large wheel and small pinion working together such is not the case. It is only possible to obtain such a result in the latter instance by using a rolling circle so large that the roots of the pinion would be greatly undercut and weakened thereby. Let it be understood that my assertion is not that two teeth are *never* in gear at once, for they are, but that at regular intervals, just when one tooth is entering into and the next one leaving contact, there is a moment when the strain is all concentrated on the flanks of one. For this reason it is prudent to reckon only on the contact of single teeth.

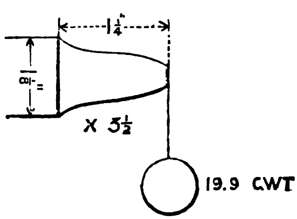


Fig. 57.

It is sometimes considered safer not to estimate the strength of a tooth on the supposition that the strain is distributed along the entire flank, but to imagine that it is concentrated on one corner only (Fig. 58). This will not affect the method of our calculation, since the triangular piece is a cantilever still, but only the dimensions upon which our

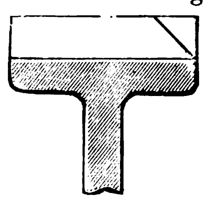


Fig. 58

* In a bevel-wheel we must base our calculations on the *mean* dimensions of the tooth.

estimate is to be formed. For badly made wheels this is undoubtedly the safer plan; but if the wheels are struck out and made properly, and the strain is calculated for one tooth only of each wheel in gear at once, there is no need to base our estimate of their strength on this assumption.

Ratio of Wheels.—Wheels are levers, in which the mechanical advantage is in inverse ratio to the radii of their arms. Also, circumferences and their radii being always proportional, it matters not whether in calculating the power or the velocity ratios of wheels we take their radii, circumferences, or number of teeth. Further, in calculating the power gained by a train of wheels, the geometrical and not the arithmetical product of the whole must be taken. Hence the rule for calculating the power of gearing is: Divide the *product* of all the wheels (either their radii, diameters, circumferences, or number of teeth) by the product of all the pinions; the quotient (friction disregarded) is the gain in power. Thus, in a train of gearing, let W, W′, W″ represent wheels of 60, 90, 140 teeth respectively, and P, P′, P″ pinions of 10, 12, 16 teeth, then, the pinions driving, the mechanical gain is—

$$\frac{W \times W' \times W''}{P \times P' \times P''} = \frac{60 \times 90 \times 140}{10 \times 12 \times 16} = 393 \cdot 7.$$

Lastly, having two proportional factors of a wheel given—to find the third

Let π = ratio of circumference to diameter = 3·14159
n = number of teeth
d = p. diameter in inches
p = pitch of teeth.

Then (1) The diameter and pitch being given, to find the number of teeth—

$$n = \frac{\pi \times d}{p}$$

(2) The number of teeth and diameter being given, to find the pitch—

$$p = \frac{\pi \times d}{n}$$

(3) The number of teeth and pitch being given, to find the diameter—

$$d = \frac{n \times p}{\pi}$$

CHAPTER VIII.

ON CORE PRINTS.

Prints not always required.—Typical forms of Prints.—Taper.—Depth.—Modifications of Prints.—"Stopping-off."—Boxes.—Coring various kinds of holes.—Top Prints.—Wrought-iron pieces cast in.—Chain Wheel Cores.—Importance of Venting Cores.—Decomposition of Water in a Mould.

AGREEABLY with the purpose stated at the commencement of this volume—that the study of general principles should be our object—we shall revert occasionally to the discussion of those matters which lie at the foundation of the pattern-maker's art, but which we can only mention incidentally in the articles devoted to set subjects. In pursuance of this intention, the present article is devoted to the subject of core prints. To treat this wide matter fully would occupy three or four such chapters, but by taking it simply in its widest bearings we shall compress our remarks into a few paragraphs.

Firstly, then, core prints are not always necessary. When the cores are large and rest flat on the bottom of the mould, they can be set in position by measurement, and their own weight, or the pressure of the top box, or both combined, will maintain them in position. But usually cores are set in their places by means of prints.

The simplest form of print is the common round or square kind, on which the apprentice makes his first essays. Then, of course, all prints which draw from the bottom of the mould are simply modifications of these, possessing taper, and varying with the shape of the holes they are indicative of. The next form is the pocket or drop print, used for casting holes in the vertical sides of a mould where a common round print could not be drawn up with the pattern. Here, when the core is placed in position, the upper part of the print is filled in with sand flush with the edge of the mould. All prints, however they may vary in appearance, belong either to one or the other of these two types.

Common round prints are tapered in the direction of their depth, the amount varying from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch in their

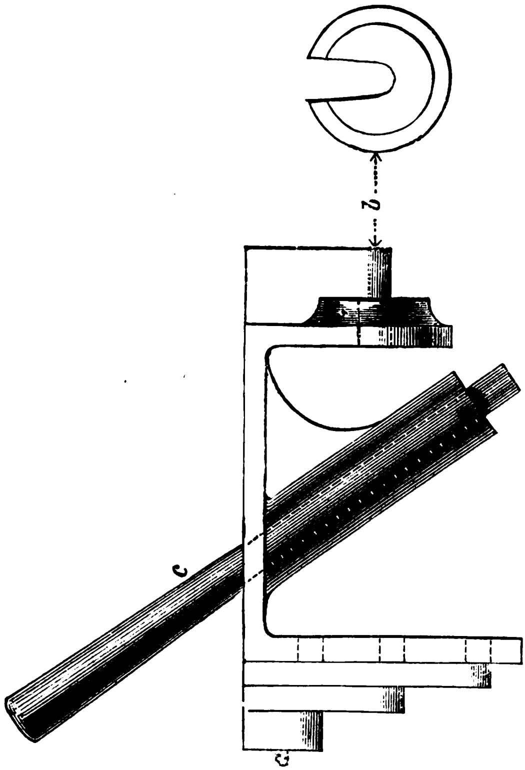


Fig. 59.

diameter, smaller prints having less, larger ones more, taper. The only object in tapering them is to facilitate their withdrawal from the sand. Their depth varies also, a print small in diameter requiring greater depth than a large one, to steady its core in position, so that while a 1-inch print may be 1 inch long, a print with a broad base, say of 8 inches or 10 inches in diameter, need not be more than ½ inch thick. The thickness of pocket prints depends upon the thickness of metal through which their cores have to be carried. If we had to cast a hole through an inch of metal, the print should be made 1¼ inch thick, to counterbalance the weight of the unsupported portion of the core. But if the thickness becomes very great we ought to have prints on each side of the pattern, in order that the core might be bridged across the mould. If, however, the core does not go right through the metal, but only a portion of the way, and the unsupported length is too great for an ordinary print to counterbalance, we simply put a print thick enough to resist the crushing of its sand out of shape by the weight of the core, and sustain the opposite end of the core by chaplets. The partly closed box, which sometimes carries a front crane roll, or the cylinder or the plunger for a large hydraulic ram, having one end closed, will illustrate my meaning.

Again, we may have three or four holes in the same vertical plane (Fig. 59, *a*). Here we should place pocket prints one over the other, the outer ones being thicker than those within, because of the greater length of core they have to carry. We should scarcely be able to make these outer ones thick enough to entirely counterbalance their cores, but should expect the moulder to hold them in place until they were securely stopped over. "Stopping over" means filling up the upper portion of the print level with the face of the mould, after the core has been placed in position. Where cores of the same size are used repeatedly in one pattern, we make a special box to fill up the print as well as to core the hole out, or, in brief, to "stop itself off" (Fig. 60; see also Figs. 44 and 45, p. 44). It is easily seen what shape the core-box must be in order to fill up the print and take out the hole; the difficulty sometimes is how best to joint it. However, this need offer no real obstacle if we remember that the only object in parting the box is to allow freedom of delivery to the core. So that the various portions of an intricate box can be removed without tearing the core, it matters little in what particular way it is parted.

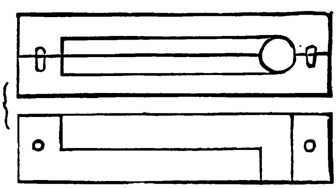


Fig. 60.

Where a print has to be stopped up over a boss, the boss must invariably be cut out to slip over the print, and not the print cut to fit over the boss (Fig. 59, *b*). This is apparent in an instant in the sand, for then a solid boss is seen to occupy the portion of the print which the moulder desires to fill up.

When a long round core has to stand at an angle in a mould, it is customary to have, in addition to the bottom print, a long tapered one in the top coming right through the top sand (Fig. 59, *c*). Here the core is thrust in through the top after the boxes are put together, and the proper bevel is thereby secured. But the danger is lest some of the top sand should be pushed into the mould by the descent of the core, and, remaining there, destroy the casting. The mould being finally closed, the workman can only rely on his sense of touch. This danger is partly guarded against by making the long taper print at its smaller end ⅛ inch larger than the core, or more effectually by bending a piece of hoop iron around the smaller end of the print, and letting that remain *in situ* to protect the sand. But some moulders will rather sustain the core at its bevel by chaplets, and only use the long print where chaplets are not available.

Where cores are carried in a line through two or more contiguous ribs of a shallow casting, pocket prints are often discarded for a round parallel print placed between the ribs. This involves no stopping over, for the joint of the mould is brought down to the centre of the print, and a long round core insures greater parallelism in the holes than two or more shorter ones would do. The advantage of this is still more obvious where there are deep bosses, projecting inwards, for increasing the length of bearing. These would have to be stopped over were pocket prints used, whereas with a round print the bosses remain intact. But if the sides are too deep to allow of jointing down to the centre of the print, and moreover too thin to allow of the bosses being drawn in, and for some reason or other it is not advisable to joint the pattern itself in the centre of the bosses, the neatest way is to take out the upper half of both boss and print with a core (Fig. 61). A block print stretching from side to side, with its ends well tapered, and a core-box of corresponding size, with half bosses and half print fastened on its bottom board, will then answer our purpose admirably.

In the case of a vertical core disproportionately long in comparison with its diameter, a bottom print is not usually sufficient to carry it steadily in the vertical position. Then we put a top print on the pattern in addition to that on the bottom. Yet this is usually only essential where it is not easy to check the upper part of the core by measurement. In a common brass bush, even if it be 10 inches or 12 inches long, the moulder can centre his core by measurement, and the top box will keep it in position afterwards. So the core in the boss of a spur-wheel can be checked accurately from the points of the teeth. But a bevel-wheel with a deep boss on the back, or a sheave-wheel one half of which is in the top box, do not afford the same facilities for measurement. So in these and similar cases it is advisable to put prints both on top and bottom.

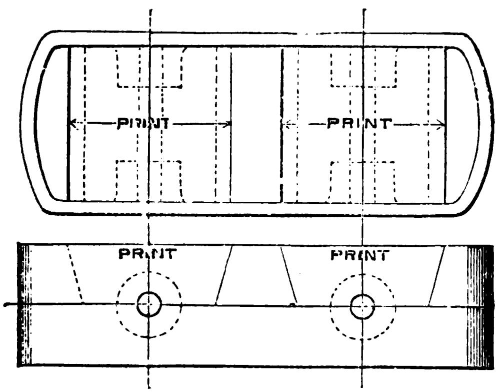


Fig. 61.

We have frequently to cast a wrought-iron eye, handle, pin, or such like, in a piece of work. Here a print precisely similar to a core print will be used, its shape following the outline of the handle, pin, or eye to be cast in (Fig. 62). The spaces. *a*, *a*, left by the withdrawal of the print, are of course filled up with sand before the mould is closed for casting.

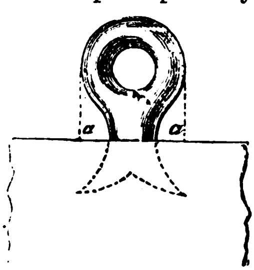


Fig. 62.

Sometimes a hole has to be cast through a thick lug or bracket in such a position that a print on each side is necessary. Yet something else in the way, a bracket, perhaps, or boss, would render the "stopping-off" of the pocket print on one side a troublesome job. The difficulty is avoided by having a common round print on this side loosely wired on, and by making the pocket print on the clear side about twice as thick as usual (Fig. 63). The core is then dropped into the pocket print, and thrust along into the round print. The vacant space behind and over the core in the pocket print is stopped up with sand as usual.

The rim of a large chain-wheel is usually taken out with cores to save the labour of cutting out a large number of link

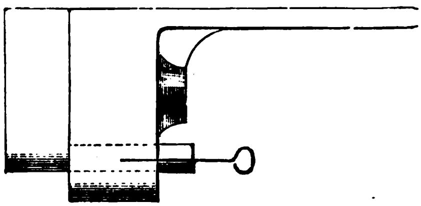


Fig. 63.

recesses in the pattern. Here, and in all jobs where the prints should well support their cores without assistance from chaplet nails, the print should be plenty wide enough.

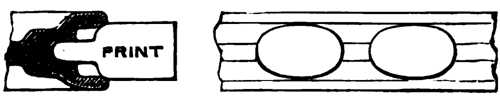


Fig. 64.

Give it, say, half as much again of bearing as is necessary to just counterbalance the cores (Fig. 64). Of the core-boxes for these wheels we shall speak in due course.*

Lastly, a core without communication with the outer air is an impossibility; no casting could be made with a core inclosed on all sides, for the gas generated by the heat of the molten iron would then be confined in the interior of the mould and form cavities in the casting—in other words, make it honey-combed or "spongy," or blow up altogether.

The theory is this: a mould is always more or less damp—that is, it contains water in a finely divided state. Water is composed of oxygen and hydrogen, H_2O. At the temperature of molten iron this becomes decomposed into the two gases, so that within a few minutes after the metal has been poured into a mould all the moisture within its influence becomes

* Chapter XV., p. 98.

gaseous oxygen and hydrogen, occupying, say, 12,000 *times the original volume of the liquid.* Of these two, the oxygen enters into chemical combination of some kind or another within the mould, either with the carbon (the plumbago or the charcoal used for facing), to form one of the oxides of carbon, CO or CO_2, or with the surface of the iron to form a skin of oxide, or with the sand to form a silicated oxide of iron (parting sand). The hydrogen escapes to the vent holes, and rushing out ignites with a loud report, burning with the blue flame characteristic of that gas. Hence it is apparent why not only the mould must be vented, but why all cores must communicate with the outer air. This, though properly belonging to the founder's craft, is mentioned in order to warn the pattern-maker never to entertain the idea of making a core without allowing an exit for the gas proportional to the bulk of the core itself.* As a matter of fact, in workshop practice holes are often cast in work in positions not indicated by the draughtsman, solely for the purpose of providing sufficient area of egress for the liberated gas, the intuition of experience being the best guide in such matters.

* The student of chemistry will readily understand why the outrush of gas from even a small mould is so great.

A c.c. of water weighs 1 gramme.

The combining weights are $\left.\begin{matrix} H_2 & 2 \\ O & 16 \end{matrix}\right\} = 18$

18 grammes decomposed become 22,400 c.c. of H
11,200 — O
33,600

that is supposing the gases were measured at 0° C.

∴ 1 gramme = 1 c.c. of water becomes—

$$\frac{33,600}{18} = 1866 \text{ c.c. at } 0^\circ \text{ C.}$$

But as the temperature of molten iron equals at least 1,500° C., this would expand the gases to—

$$\frac{1866 \times (273 + 1500)}{273} = 12,118 \text{ c.c.}$$

or 1 c.c. of water becomes 12,118 c.c. of mixed gas.

CHAPTER IX.

ENGINE CYLINDERS.

Striking out.—Views required.—"Lagging up."—Head Metal.—Turning.—Passage Block.—Steam-chest Flange.—Prints.—Exhaust.—Feet.—Passage Core-box.—Exhaust Core-box.

ENGINE cylinders are of all sizes—from 2 or 3 inches to 8 or 9 feet in bore, and of most varied types. The smaller ones are cast from patterns, the larger from loam moulds. We will take a simple illustration of a high-pressure cylinder of moderate size, and describe the making of its pattern before we pass on to the loam cylinders. This, like most of our work, must be struck out on the drawing-board. We want a longitudinal section, cutting through the steam ports and valve face (Fig. 65), and a transverse section through the same face and the exhaust port (Fig. 66), also a plan of the cylinder looking into the ports (Fig. 67). Make the drawing to the sizes of the finished casting, adding the due allowance afterwards for turning and boring. Taking a cylinder of 6-inch bore and 10-inch stroke, let us give it certain definite proportions for convenience of illustration, and not as fast dimensions.

	in.
Length of cylinder	$14\frac{1}{2}$
Thickness of metal in body	$\frac{9}{16}$
,, flanges	$\frac{3}{4}$
Length of port	$3\frac{1}{3}$
Width ,,	$\frac{7}{16}$
,, exhaust	$\frac{15}{16}$
Metal round ports	$\frac{9}{16}$
Length of valve face	7
Width ,, ,,	$4\frac{3}{4}$
Length of steam-chest flange	10
Width ,, ,,	$7\frac{1}{2}$
Thickness of ditto	$\frac{5}{8}$
Distance between ports	$\frac{5}{8}$

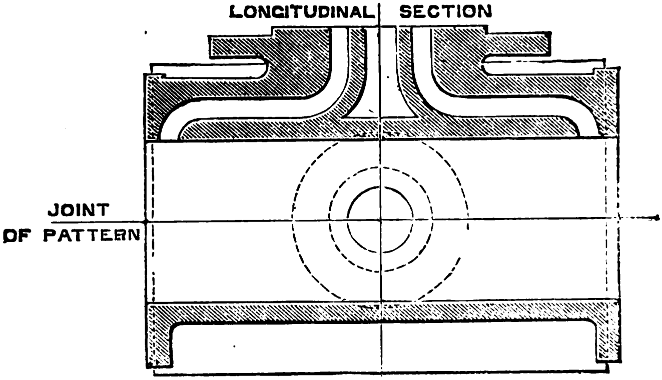


Fig. 65.

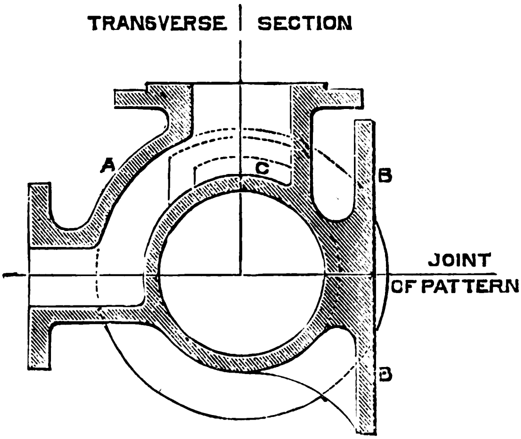


Fig. 66.

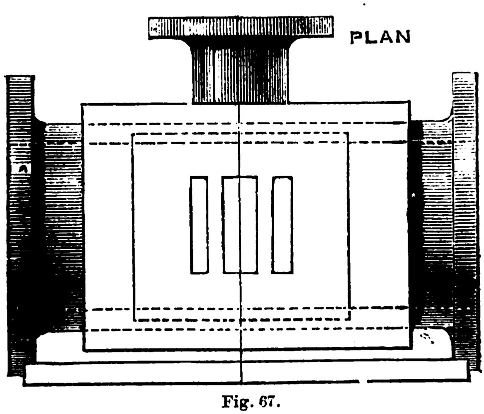


Fig. 67.

A foot or a pair of feet will be required for the purpose of bolting the cylinder on to its bedplate or framing, and their shape and position will be determined by the shape and position of the part to which they are to be attached.

When about to make the pattern, commence with the circular body. In order to mould well, this must be jointed longitudinally with dowels; and unless a piece of very dry timber is available, it is not customary or wise in a standard pattern to make it in the solid. The proper way to make cylinders, as well as large pipes, is to "*lag them up*." Longitudinal strips are glued and secured with nails or screws to transverse ends which have been planed hexagon, octagon, or polygonal in form, the size across the flats being determined by the thickness of the stuff in the *lagging*. Dowel the end blocks in their joints, mark out into flats, and saw and plane perfectly square across the thickness of the stuff (Fig. 68, section).

Now lay the joints of those halves which contain the dowel *holes* on the bench or on a true joint board, at the distance over all which coincides with the extreme ends of the pattern. In this instance this will be 14½ inches = length of cylinder + say 3 inches at each end for prints + 2 inches for "head metal" = in all to 22½ inches, and this will be the length of the lagging also. The object of head is this :—When metal is poured into a mould, dirt and scurf, being light, float on the surface, and along with entangled air bubbles rise to the top, making the upper part of a casting spongy and unsound. In an engine cylinder this porosity would be a fatal evil, diminishing its strength and permitting escape of steam. So these lighter matters are allowed to float into a ring of "head metal" of the same diameter as the cylinder, and of sufficient height to contain them all. It is scarcely necessary to remark that this is turned off the casting and thrown away.

Sometimes the pattern proper finishes with the head metal, and the prints are turned separately and screwed on the ends. This is a matter of no importance; but if our stuff is long enough to turn prints as well as body (and we will suppose this to be the case) our angular transverse ends will occupy the "out and out" position. Now take one of the pieces of lagging, plane up the face quite true, and bevel both edges. The width on the face will be the same as the flats on the transverse ends, and both edges will be bevelled so that if projected they would meet at the central axis of the cylinder. Glue and screw this first piece in place with one edge resting on the joint board or bench; chalk its upper edge, and fit the second piece against it, until the chalk shows a fit everywhere; plane the next edge to the same bevel at the proper width, and then glue both the face and the chalked joint, and screw. In this way carry the lagging round the first half of the pattern. Now turn over this first half, lay the dowel ends in place, and build up the second half in the same fashion. Allow the glue time to set hard, and then chuck in the lathe with centre plates, which are simply square pieces of sheet iron or brass with screwholes at the corners, and made—one of them to receive the lathe-fork, the other counter-sunk to run on the back centre (see Figs. 210, 211, page 160). When screwed in place, they form the temporary centres of the pattern, and retain the two halves securely together while being turned. The screws which hold them on should be put in firmly in order to prevent the work flying asunder while in rapid rotation.

Now, having our cylinder in the lathe, and being assured that everything is well secured, rough it down to within $\frac{1}{8}$ inch of the body size with a sharp gouge. If belts are desired, the pattern must be roughed to the size of the belts first, and afterwards turned between the belts to the body size. Finish the body by scraping with a firmer-chisel. Mark on the body so turned a

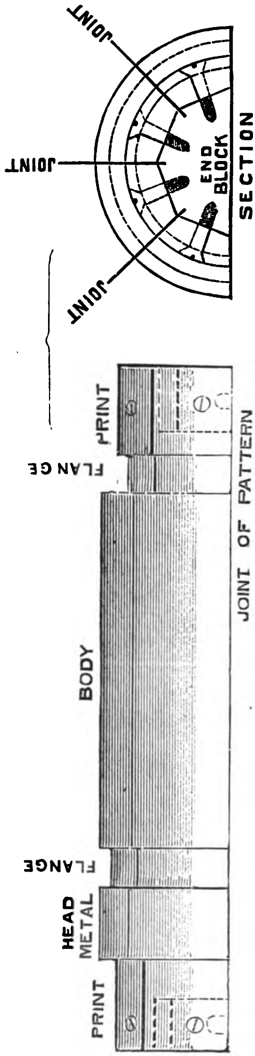


Fig. 68.

line at the distance of one print from either end, equal to 3 inches, then another line at a distance from the first equal to the length of cylinder, + the allowance for facing on flanges, — $\frac{1}{8}$ inch. on each flange, equal to $14\frac{3}{4}$ inches in all. From these two lines strike two others equal to the thickness of the flanges with their hollows, allowing, say, $\frac{1}{2}$ inch for hollow. Turn out grooves for the flanges in the spaces thus marked; measure off 2 inches, the length of the head metal, and that will leave 3 inches for the length of the second print. Turn these prints down to $5\frac{3}{4}$ inches diameter, parallel, no taper being required—the cylinder moulding on its side; $5\frac{3}{4}$ inches diameter will give the proper allowance for boring out on a small cylinder, but in larger ones we should have rather more, from $\frac{5}{16}$ inch to $\frac{7}{16}$ inch. Glass-paper and varnish the body, take it from the lathe, and remove the centre plates. Fig. 68 will represent one half the pattern at this stage. Turn the flanges in halves on the face-plate to fit the grooves, not forgetting the additional $\frac{1}{8}$ inch in thickness for facing. They may be screwed on the body or left loose—it is of no consequence which.

The ports and valve face will claim our next attention. Get a block of wood, wide enough and thick enough to include the ports and the metal inclosing them, and fit it between the

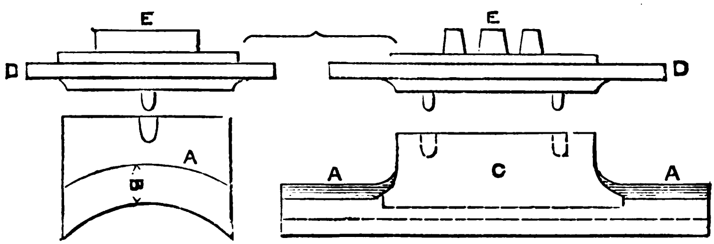


Fig. 69.

flanges and round the curve of the cylinder body (Fig. 69). Having hollowed the inner face, plane the outside rounding and concentric with the cylinder body (Fig. 69, A), making the thickness equal to the width of port and of the metal bounding it (Fig. 69, B). Recess this across the centre to receive the block through which the ports curve upwards into the valve face (Fig. 69, C). This last piece should extend as far as the termination of the hollow on the under side of the steam-chest flange. Be careful to have the top of this block parallel with the joint of the pattern. Laying the half pattern on a true board, rest a straightedge over the block, and, measuring near its extremities, adjust its edge until it shows the block parallel with the board. Then screw in place. Next, prepare the flange for the attachment of the steam-chest (Fig. 69, D). Make it sufficiently thick to allow for facing, and also for working the hollow on its under side; dowel it on the port block, keeping it parallel up and down the cylinder. Work out the hollow on the back, using rebate, and carpenter's round planes; make the valve face and nail it on, and on that again nail, screw, or dowel the prints for ports and exhaust (Fig. 69, E). Leave these prints barely $\frac{1}{8}$ inch narrower than the finished ports, so that the fitter may chip and file their edges accurately for the cut-off of the steam.

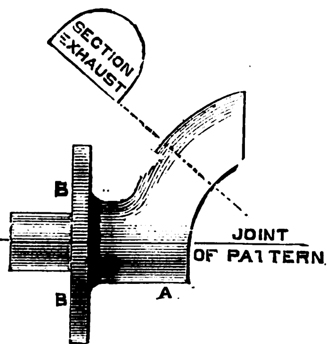


Fig. 70.

Now fit a block of wood for the exhaust, the D-shaped piece of pipe which comes from underneath the steam-chest flange downwards to the joint of the pattern (Fig. 66, A). Work the portion which fits the body of the pattern with a gouge, and the outer part with a chisel, using a templet struck semicircular in shape (Fig. 70). A distinct half-round block will be fitted on the other half of the cylinder body, forming a continuation and termination of the D-shaped pipe (Fig. 70, A). Make the exhaust flange and print in halves, and screw one half on each portion of the exhaust pipe, the joint of the flange coinciding with the joint of the pattern (Fig. 70, B, B).

The feet in our pattern are at right-angles with the steam-chest face (Fig. 66), and can be fastened on permanently to draw with the pattern; but had they been on the side opposite to the valve face, they and their bracketings must have been held in place with temporary screws only, put in from the inside of the lagging. Put hollows behind these feet, and allow for planing on their faces, B, B.

We now consider the core-boxes. They are two in number, the steam passage and the exhaust. No box is requisite for the centre core, for the core maker strikes that against the edge of a loam board. In this case it is simply a board a few inches longer than the cylinder and prints, having one edge planed straight and *chamfered*. The core-boxes, however, are not easily made by an inexperienced hand. By adhering to the following directions, and exercising a little "insight," no great difficulty need be experienced :—

Take the passage box first (Fig. 71). We have the curved part drawn in section (Fig. 66, c, and Fig. 65). Prepare, therefore, two pieces of wood, just the width of the port $=3\frac{1}{2}$ inches, and exceeding its extreme length by about

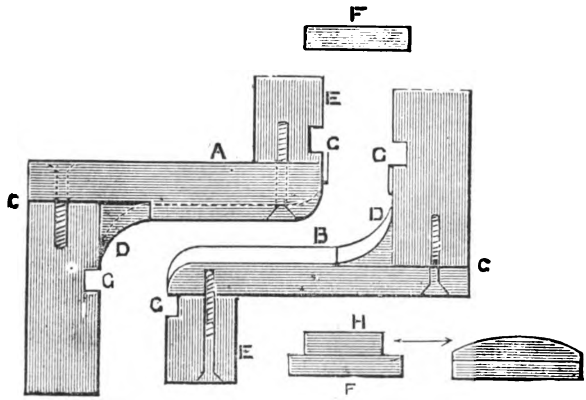


Fig. 71.

4 inches, and sufficiently thick to allow of planing out the curves, and giving an inch of wood in the thinnest part besides. For the outer curve of the port (Fig. 71, A) *hollow* one of the pieces, using a templet struck from the drawing, and for the inner curve *round* the other piece (Fig. 71, B).

We now want to form the ends and their curves. Evidently the longitudinal central lines of the pieces just worked correspond with the port lines on the longitudinal section we have drawn upon our board. So we set the *central* line of each piece in turn over its corresponding line on the board, using a set-square for the purpose, and we see at a glance that we must block up at the ends of our straight pieces in order to form the terminations of the box, and we also see the amount of blocking that is necessary. Rebate out across the curved faces for the reception of these blocks, and glue and screw them in place, C, C. Fit and glue in like manner the bits which are to form the hollows, D, D, and work them in place. Screw on the blocks, E, E; connect the two portions of core-box with transverse ends, F, F, letting them into shallow grooves, G, G, G, G, in the usual way, to prevent their ramming out of position. It will be remembered that our prints were made narrower than the finished parts to allow for exact adjustment of the valve. In that end of the core box, which corresponds with the print, thin strips of wood will be glued to diminish the opening to the width of the print. These strips may be $\frac{1}{2}$ inch wider than the thickness of the print, giving $\frac{1}{2}$ inch for depth of chipping strip in the casting. The planing will take

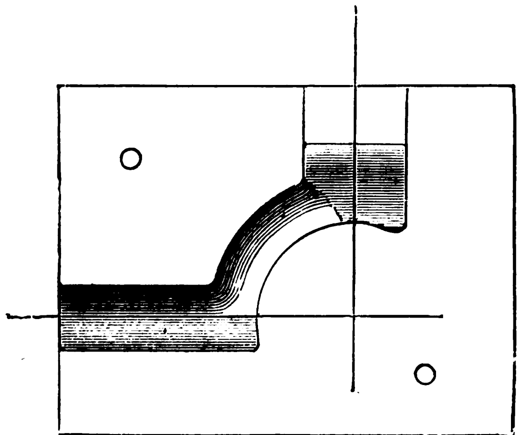


Fig. 72.

$\frac{1}{8}$ inch out of this, and the wear of the valve will reduce its thickness further in course of time.

The other end of the core will fit the body core of the cylinder, and must, therefore, be hollowed to that curve. Fit a piece in that end, and with its rounding face H towards the *core space;* this will impart to the core the hollow form required.

Lastly, there is the exhaust (Fig. 66, A). The joint of this box will correspond with the transverse section of the cylinder, cutting the exhaust passage along the centre. Two pieces of wood are required, sufficiently long and wide to include the whole course of the exhaust with its prints, with about a couple of inches of timber besides (Fig. 72). They should be about an inch thicker than the semidiameter of the passage. Face both pieces truly, dowel together, and square one side and one end. To these corresponding faces transfer, by means of square and compasses, the sectional view of the exhaust port from the drawing board, extending that view to include the prints. The ends of the prints will coincide with the side and end we have squared. Gauge half the depth of the oblong portion of the port on each half of the box, and similarly strike on each half the circular portion of the port. Cut inwards with chisel and gouge, using templets to insure accuracy away from the immediate vicinity of the ends. Be careful that the halves of the box correspond, so that the core shall show no overlapping edges in the joint, and fasten the chipping strips against the valve face as in the inlet core-box. Fig. 72 shows one half of this box thus worked out.

CHAPTER X.

ENGINE CYLINDERS STRUCK IN LOAM.

The use of Loam.—Foundation-plate for striking on.—Bottom-board.—Body-board.—Attachments of Cylinder.—Loam Bricks.—Top-board.—Head.—Central Core.—Closing the Mould.—Variety of Design in Cylinders.

A MOULD taken from a wooden pattern is the most convenient and economical method of making a small cylinder, but it would obviously be too expensive in one of large diameter, say, ranging from 3 feet to 8 or 9 feet. If, then, we had to make a cylinder so large in diameter, and perhaps 6 feet, 8 feet, or 9 feet long, we should "strike it up" in a loam mould. Foundry loam is a mixture of various sands and horsedung, which mixture, unlike the common sand, has the property of hardening when dried. Being plastic when in the wet state, it can be "struck up," or made to assume any shape that may be required. The necessary outline is imparted to the mould by a board having a "chamfered" edge, which board swivels on a bar set upright, and working in a step. Portions of work, not circular, as valve faces, feet, passage blocks, &c., must have their corresponding patterns made separately, just as in the case of an entire wood pattern, and embedded in the loam, there to remain until it is dry, when they are drawn out as from ordinary sand.

In our large cylinders we begin with the bottom flange. Make a rough cast-iron plate, 5 inches or 6 inches larger than the diameter of the flange, and about 3 inches thick; cast four projecting lugs on its circumference, and let its upper surface (Fig. 73, A) be studded over with points or "jaggers" to hold the loam. A hole in the centre is necessary, to allow the central striking bar to pass down to its socketed footstep. This plate will be placed on any convenient support, usually wooden blocking B, B, and daubed over with thick loam. The first striking board, C, notched to correspond to the semidiameter of the flange, minus half the diameter of the striking bar, D, also shouldered back to the thickness of the flange, and carried out parallel a few inches beyond its edge, will be swept over this surface. By repeated strikings, and the final application of thinner loam, the shape of the edge and face of the bottom flange, together with a joint surface, will be obtained. This will then be lifted by the projecting lugs which are cast on the foundation-plate, taken to the stove, and dried. When dry, it will be sufficiently hard and firm to sustain the body of the cylinder which will be built upon it (the latter might, however, be built on a separate plate, and then transferred). The outer board for striking the body, framed together with half-lap

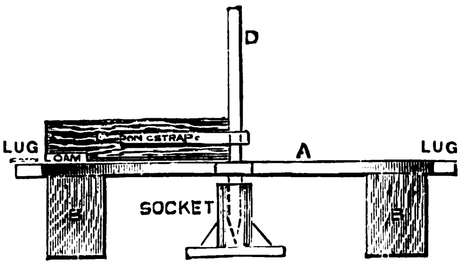


Fig. 73.

joints, cut at the top to form the flange and the upper joint, and chamfered, will be screwed to the bar, with its bottom end level with the joint of the flange (Fig. 74). The flange itself will be temporarily filled with sand. On the flange joint already made the moulder will build up the body of the cylinder. Outside, and about an inch away from the edge of the board, he will build courses of bricks, bedding each successive course on a thin layer of loam, until the proper height is attained. Within this wall of bricks loam will be laid, and struck truly circular by means of the board. The upper portion of the board will strike the top joint, coinciding with the face of the top flange, and that joint will have a "check" about 1½ inch deep, and standing about 4 inches away from the edge of the flange, which check becomes a guide for the concentric setting of the top mould. Passages, valve faces, and flanges, of one type or another, will be required. These, as we said before, will be made as patterns, and embedded in the loam, and, of course, where they come the bricks must be left out. Portions of these may require to be loose for convenience of drawing in, and while some pieces will be drawn *into* the mould, others perhaps, as steam-chest

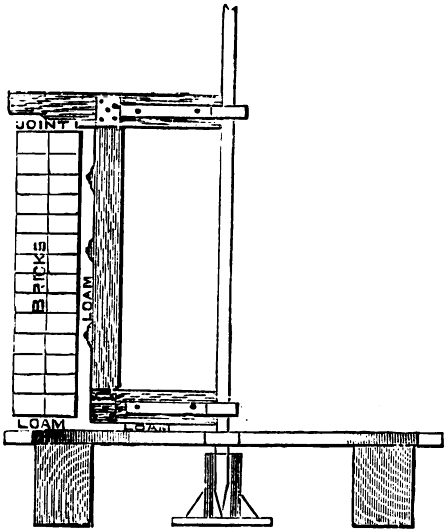


Fig. 74.

flanges, will have to be drawn from the *outside*. Where a flange is drawn from the outside, its face will be made by a

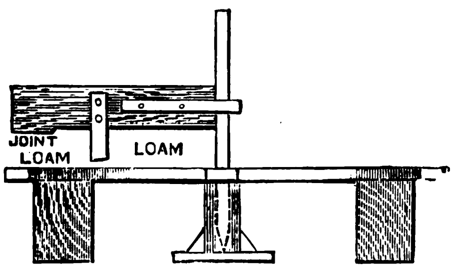


Fig. 75.

flat cake of loam laid against the outside after the mould is finished. Where there are wide flanges or brackets in close proximity to the body of the cylinder, there is a danger of their breaking off during the contraction of the metal, owing to the unyielding nature of the bricks. In such cases "loam bricks" are used, *i.e.* bricks made of loam and dried. These will crush and give more readily to the shrinking of the metal.

The face of the top flange will be made by a board showing a joint exactly the counterpart of that on the body-board, having its "check" cut the reverse way to that shown in Fig. 74. A tongue must be screwed upon it to give the proper head metal, say six or eight inches (Fig. 75). The flange face will be struck on an iron plate similar to that which was used for the bottom.

Meanwhile the outside of the cylinder will have become sufficiently set for removal to the stove. It will be detached from the bottom plate for this purpose, and while it is drying the centre core, representing the bore of the cylinder, will be struck up. Here also a board in a vertical position will be used, striking a coating of loam on a body of bricks (Fig. 76). This, too, will be dried and removed.

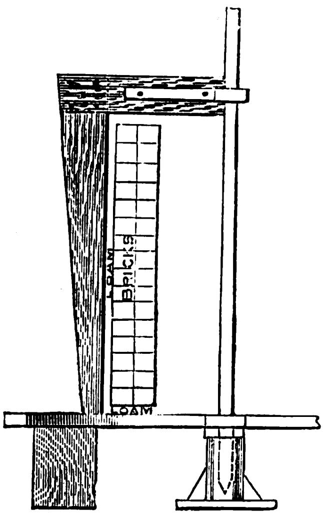


Fig. 76.

All the parts having been struck and dried, the moulder then blacks their surfaces and puts them together. Fig. 77 shows the mould in section. The passage cores, not shown, for which core-boxes must be made in the usual way, as described in the last chapter, will be fixed, and the top and bottom parts of the mould will be secured by bolts, embracing the lugs on the top and bottom plates. The whole will then be placed in the foundry pit, due provision having been made for the bringing off the gas from the mould, and the entire affair is rammed round with sand previous to casting.

Cylinders vary very widely in general design; consequently a detailed description of one pattern will not apply to another. In this, as in many other classes of work, a pattern-maker will seldom get two jobs exactly alike. He must, therefore, find safe and sufficient guide in the general principles of his trade, assisted by the teachings and warnings of experience. Thus he must not only foresee whether or no his pattern, when constructed, will deliver from the sand, but whether the cores, as well as the mould, can be put together in detail, and so securely that nothing shall be washed out of place by the rush of metal. He will also consider where core prints can be used with best advantage, since sometimes prints will be dispensed with and "chaplets" used instead; frequently also prints in cores will form the supports for other cores.

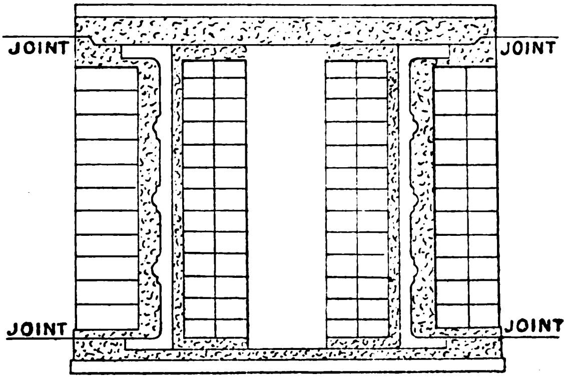


Fig. 77.

Cylinders are sometimes cast double; frequently they are jacketed; often the steam-chest forms a part of the cylinder casting. The feet are sometimes in awkward positions and of queer shapes. Of late years engines have come into common use in which cylinder, bedplate, and guide-bars are cast all in one. In these matters of detail the general principles we have laid down, coupled with the knowledge to be gained by experience, are sufficient guide to the workman who may never have seen a piece of work precisely similar to that which he may at any moment have to take in hand.

CHAPTER XI.

ON ENGINE BEDS AND BASE-PLATES IN GENERAL.

Definition of a Bedplate.—Horizontal Engine Bed.—Methods of Moulding.—Way of Casting.—"Boxing-up" of Patterns.—By two Methods.—Attachments of Bed.—Types of Bedplates.—Core-boxes.—Buckling of Castings.—Theory at Fault.

THERE is no limit to the forms which bedplates may assume. But however their details may vary, a bedplate is a bed-

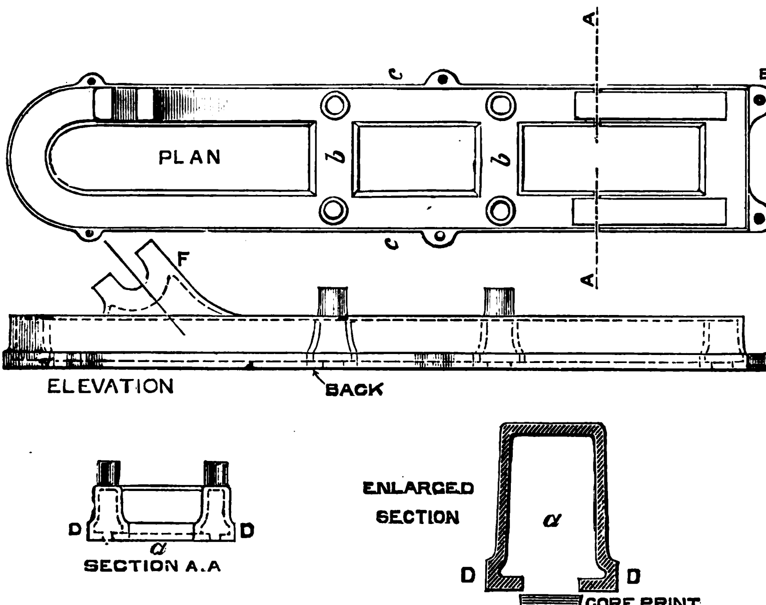


Fig. 78.

plate after all. Any piece of casting which becomes the foundation for machinery may be termed a bedplate or baseplate.

In a general way we should define it as a plate of metal rendered rigid by means of ribs or flanges. There may be bearings, brackets, facings, lugs, bosses, recesses, mouldings also, which will complicate the pattern in a greater or less degree; but the remarks following will apply in a general way to all castings of this class.

We will, first of all, give detailed directions for the making of a common type of engine bed, and afterwards pass on to observations of a more general scope. Say, then, we have to make a bedplate for an engine of the ordinary horizontal type. The bed is of a type which in these days of compact and cheap engines is becoming somewhat antiquated; but it is purposely chosen because it illustrates well the method of "boxing up," and affords a good medium for the remarks we wish to make on beds in general. It is a plain bed shown in Fig. 78. Two ways of constructing it would occur to the pattern-maker. One would be to make the pattern like the casting, allowing everything to deliver itself; the other would be to take out the space between the ribs with dried cores. Selecting a bed having a section like Fig. 79, the first method would answer very well; but taking one with a section like Fig. 78, the second plan would be preferable. Where the pattern delivers itself, the sides (Fig. 79, *a*, *a*) must be tapered, or set out of perpendicular, say $\frac{1}{8}$ inch or $\frac{1}{4}$ inch, depending on the depth of the bed; and the flat ribs or flanges, *b*, *b*, must be held only temporarily with wires or "skewers," so that after the pattern is rammed up they may come away loosely along with the body of sand which forms the hollow portion of the bed, to be subsequently withdrawn sideways. But where the hollow portion is taken out with cores, as in Fig. 78, the pattern will be made just as though the casting were not to be hollowed out at all, and core prints on the back (enlarged section) will give the only indication that the bed is not intended to be solid. Let us premise that when we mention the back of a pattern we mean that portion in the top of the mould—in the case of our bed, that portion which bolts on the foundation-stone.

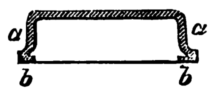


Fig. 79.

Now, it would always be more convenient to lay cores in the bottom part of a mould than to hang and screw them in the top. But as we have already mentioned, when speaking of cylinders, the bad metal always rises uppermost, and it would be highly detrimental both to the strength and appearance of a bedplate to have a quantity of scurf and air bubbles spread over its surface, where facings, bearings, bosses, &c., require to be faced bright, and where a sound plate is necessary to sustain the complicated strains and stresses of moving parts. Hence it is usual to cast beds with the plate downwards, and to hang the cores in the top.

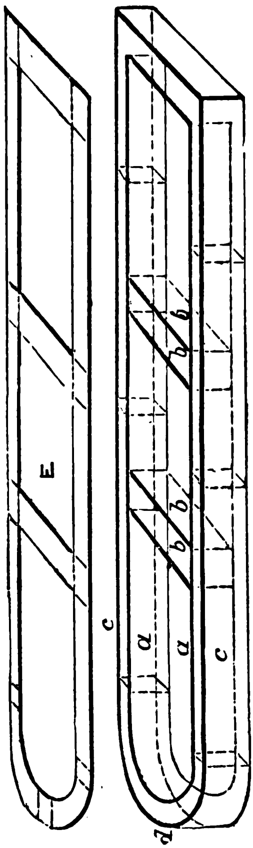


Fig. 80.

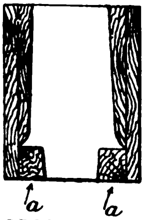
If we had to make a small bed-plate for a four or six H.P. engine, we should plane up solid stuff and mortise the crossbars (Fig. 78, *b*, *b*) into the sides, *c*, *c*, a process sufficiently simple to need no descriptive detail. But if the bed were a large one, say ten or twelve feet in length, we should "box it up." In illustration, suppose we had a plain rectangular piece to box up, 12 feet long, with a 9-inch by 6-inch cross section, and had 1-inch stuff available for the purpose, we should get out the two sides 9 inches wide, and the top and bottom each 4 inches wide by the 12 feet in length, drop the top and bottom between the sides, and nail together. Internal support would be given to the "box" by cross-bars or blocking pieces placed at intervals of about a foot. By building up pieces of heavy section in this manner a saving of timber is effected, and the liability of the pattern to warp and twist out of truth is lessened.

We can apply this method to our bed in one of two ways. The sides and cross-bars may be each boxed up separately—squared off to their respective lengths, and fastened together by tightly fitting dowels, assisted by screws driven in obliquely. The better method, however, is to frame the top and bottom plates of the pattern together with half-lap joints (Fig. 80). Then to take the pieces intended for the sides and screw them on separately through one plate, first remembering to screw the inner sides, *a*, *a*, of the bed to the ends of the cross ribs, *b*, *b*, *b*, *b*, before the outer sides, *c*, *c*, are put in place. The sweeped or curved end, *d*, may be built up with an outer and inner course of circular segments, or simply of circular arcs. Then, when the sides are all complete, place internal cross-bars, to insure the necessary rigidity during ramming up, and screw on the top plate, E.

Proceed to dress off all overlapping joints, and to mark out all centres. Dowel prints $\frac{1}{2}$ inch or $\frac{3}{4}$ inch thick on the back to carry the lightening cores, for if screwed fast, the top sand, on being lifted, will be torn away; if dowelled they come up with the top, and can be taken out one by one. A moulding, D, D, will be carried round the lower edge of the casting; plane this to required shape in strips, and screw on. Round the semicircular end it will be "saw kerfed" after carpenters' fashion, or it may be worked in short sweeps with gouge and chisel, which is the better way of the two. Lugs or ears for bolting down, E, will likewise be made, and screwed to the outside of the moulding. A bearing, F, will be cast on to carry the crank-shaft. It will be at an angle of 45° or thereabouts with the face of the bed, and will require to be drawn from the sand *parallel with its own centre line.* Therefore it will be dowelled, and left loosely in the mould. This also will be lightened with a core, and the recess for the reception of its brass bearing will be either taken out with a core or cut in the block, it is immaterial which. Bosses for the guide-bars are turned and pinned on. Facings for the cylinder will complete the bed.

I cannot recall to mind any type of bed casting which cannot be made in one or other of the ways which I have indicated in this chapter. Broadly, then, they may be divided into beds either solid or boxed up, and beds the counterparts in shape of the castings; in the latter case leaving their own cores, in the former hollowed by dry sand cores. In one or other of these methods, or by a combination of both, all bedplates can be made. In some classes of work drawbacks are useful; but as a chapter (XX.) is devoted to this and kindred subjects, we will not enter into it here.

The core-boxes remain. They are readily made. The sides, including the depth of the core together with its print, are grooved out for the reception of their ends. Flanges are dropped within the box like the internal flanges in the casting, but *thicker* than those by the added thickness of the *print* (Fig. 81, *a*, *a*). As the cores are sometimes of different lengths, though of the same section, one box is made to do duty for them all, their various lengths being given by an adjustable sliding end, screwed where required. The lightening core in the bearing will require its special box, and will be adjusted by chaplets—a print on the bottom not being available; or it may be screwed through one of the long cores into the top. A special box may also be made for the semicircular end, or, if economy is to be studied, the end core may easily be strickled. All that is necessary then is a strickle about an inch thick, cut to the shape of the core section, and a thin cast plate of iron to strike and dry it upon.



SECTION OF CORE BOX
Fig. 81.

The conclusion of this chapter will be a fitting occasion to say a word or two upon the "buckling" of castings, and of the measures to be adopted in order to guard against the evil of castings coming out crooked when they ought to be straight. The moulder may, by judicious cooling, do much to minimise this evil; but the issue depends chiefly on the relative proportions given to the patterns. Yet proper proportions once attained, slight departures from these will so modify the conditions of regular cooling that it is very difficult, almost impossible, to lay down any reliable rules in these matters, or to say beforehand how much a casting in which the proportions of metal are unequally distributed will curve in cooling. The only useful guide in these things is that afforded by the constant habit of observation and a long experience. Our engine bed will certainly curve in cooling, so that if the pattern were made straight the plated portion of the casting would be hollow when cold. To what extent it would curve it would be impossible to say without previous experience. It may be $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, or $\frac{1}{2}$ inch, according as the moulding and inner rib are thick enough to compensate in a greater or less degree for the larger extent of metal in the top plate. We therefore *round* the pattern to the same extent that we expect the casting to go *hollow*, and in the *opposite* direction.

Yet, although a long narrow bed will curve to a considerable extent, a broad plate made double for a pair of engines will be found to remain very much like the pattern. And the rule appears to hold good that the narrower the casting the more liable it is to warp. Breadth apparently gives rigidity, since on a long narrow casting a very slight excess of metal will cause a curve in the direction of that excess, while on a broad casting it would have no ill effect. Other conditions being equal also, a light casting will always "go" more than a heavy one, and will be influenced by slight modifications that would not affect the heavier one. The quality of metal, too, is not without its influence, hard iron being more liable to curve than the softer kinds. Every now and again, however, things crop up in foundry practice which appear to invalidate one's pet theories on this subject.

CHAPTER XII.

FLYWHEELS.

Pattern Wheels.—Wheels struck up.—Wheels with Cast-iron Arms.—Striking the Core-bed.—Size of Cores.—Form of Core-box.—Laying Cores in position.—Top part of Mould.—Wheels with Wrought-iron Arms.—Sweeping up the Ring.—Core-box for the Arm Bosses.—Casting of Central Boss.

FLYWHEELS permit of very little variation in design. We may divide them into two classes—those with cast and those with wrought-iron arms. The former are the more rigid, the latter are the safer.

Except in the case of standard wheels made for engines which are a speciality, and which, therefore, require a repetition of castings all exactly alike, very few flywheels are made from patterns, but are struck up. If, however, we had to make a pattern for one of these standard wheels, or one for a small engine, we should proceed as follows:—

Build up the rim in courses of segments, as in the case of a toothed wheel (p. 18), and lock the arms together, according to directions also previously given (p. 25). When the rim is built up to half its full thickness *plus* half the thickness of an arm, turn its inner portion to the correct diameter, and notch out recesses to receive the ends of the arms. Glue these in, and above them glue on the remaining courses of segments. Then complete the turning of the rim, and work the arms to shape (Fig. 82). If the wheel were large it would be more convenient to work the arms before glueing them in place, leaving only the radii which merge into the rim to be finished in position. Suitable bosses will then be turned and screwed on the

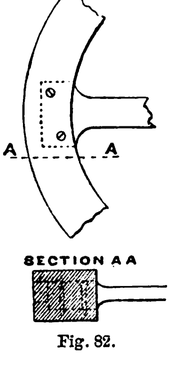


Fig. 82.

centre of the wheel, and the core print put on the centre of the boss which is in the down side of the mould.

But suppose we have to make a large wheel, ranging anywhere between 4 feet and 12 feet in diameter, without a pattern. We should proceed in this way. We should make a board chamfered like a loam board, and, like it, fastened to a centre bar (Fig. 83), to strike a ring of sand of the same diameter as the periphery of the wheel, the top edge of which ring would be struck off level by the board to form the joint for the top of the mould. The disc inclosed by this ring would be struck to a true plane of sand at a depth below the joint equal to the thickness of the wheel rim. During the process of striking, the sand forming the outside of the rim will break away and fall down to a certain extent. A sweeped piece, worked to the proper radius and depth, will therefore be necessary to mend this up smooth and sharp (Fig. 84).

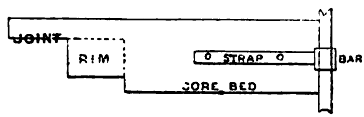


Fig. 83.

Fig. 84.

Further, if the flywheel be shallow, the striking board must be modified a little. From the inner diameter of the ring right away to the centre it must be cut deeper by 2 inches or 3 inches, thus recessing the bed below the edge of the rim by that amount (Fig. 83), where the core-bed is seen to be below the face of the rim. The object of this is to get sufficient depth of sand and grid room in the cores which are to form the arms. There should not be less than 1½ inch or 2 inches for sand, and 1 inch for grid allowed over the thickest part of the arm.

Two cores, placed face to face, make up an arm. They are jointed in the circular plane of the wheel, and extend from the inner diameter of the rim to the central boss. If, then, our bed were level with the edge of the rim, our core-box would be just half the depth of the rim. If the core-bed were sunk lower than that edge, the core-box would be thicker than half the depth of the rim by that amount.

The box must be sufficiently wide to give 3 inches or 4 inches in breadth of sand for radial jointing where the cores abut against each other around the boss. There should also be enough sand to include the radii or hollows where the arms sweep into the rim. It will be framed together in the usual fashion of rectangular core-boxes, with two sides (Fig. 85), having their two ends kept in position by shallow grooves. The end which represents the inner diameter of the wheel will be hollowed to the same sweep as that diameter. At the opposite or boss end, two symmetrically shaped joint blocks, *a*, *a*, will be fitted, including between them an angle of 60°, that being the angle which the cores will occupy in relation to

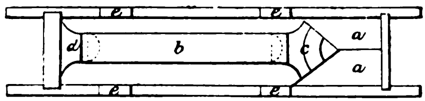


Fig. 85.

each other in the mould for a six-armed wheel. On one edge of the box so made a bottom board will be dowelled.

We have now our box in outline, requiring the arm to complete it. As the cores are to be jointed in the centre, both top and bottom cores must evidently be alike, and our arm will represent only a *half* section.

Prepare, therefore, three pieces of wood, representing respectively the straight portion of the arm, *b*, the sixth part of the boss, including the hollow by which it sweeps into the straight arm, *c*, and the sweep curving into the rim, *d*, each in half section. Dowel or screw these in the centre of the core-box and upon its bottom board. A sixth part also of the central core print may be put on the boss segment, if the box is deep enough to allow of this, or the core may be centred in the

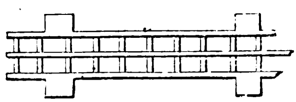


Fig. 86.

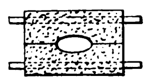


Fig. 87.

mould after the arm cores are laid in place. Notches, *e*, *e*, will be cut out on the top edges of the core-box to take the grids (Fig. 86). A grid is a cast-iron frame of latticework, which the moulder uses for the same purpose as the bricks and plates in a loam mould, viz. to give rigidity to the core. Those portions of the grid which project beyond the core are in this case also used for the purpose of screwing the top and bottom cores together before casting.

The cores, when made, are dried, blacked, jointed (Fig. 87).

and laid in the mould, as indicated by the dotted lines in Figs. 88, 89. There will then be open spaces, *a*, between each double core, which must be filled up to form that portion of the rim not already formed by the sweeped ends of the arm cores. These intervals may be filled up either by distinct cores, involving a box, or by a sweep, against which the moulder will ram green sand, similar to the one used for mending up the outer sand, but cut in the opposite way, viz. hollow, and of the same radius as that of the inner part of the rim.

Then there remains the top of the mould. This is struck by a board, and generally in loam—sometimes, however, in green

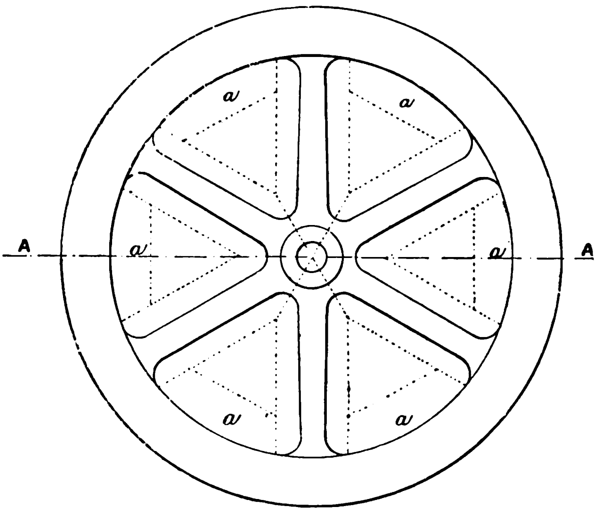


Fig. 88.

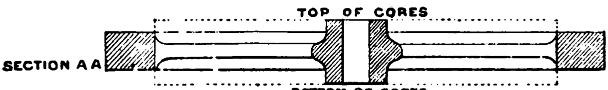


Fig. 89.

sand, viz. ordinary moulding sand. If in loam, it is struck on a circular cast-iron plate, roughened over as usual to hold the loam; if in green sand, a top-part box will be used. If the cores are deeper than the rim, as in Figs. 83, 89, the board will be shouldered as in the bottom. This completes the wheel as far as the pattern-maker's work is concerned.

But in wheels running at high speeds, and especially in wheels badly proportioned, people have learned to distrust cast-iron, and though the massive rim is retained, it is in many cases considered preferable to make the arms of wrought-iron. In wheels made entirely of cast-iron the disproportion often existing between the heavy rim and the comparatively slight arms sets up initial strains within the casting at the time of cooling, which become a perpetual source of insecurity. Hence reason and experience have decided against the use of such wheels for quick-running and heavy machinery, and in favour of those with wrought-iron arms. The strength of these wrought-iron arms also must bear a proper relation to the momentum of the wheel, else they will twist off close to the boss, as I have seen in more than one instance.

To make such a wheel, quite a different mode of procedure must be adopted from that just described. In the first place

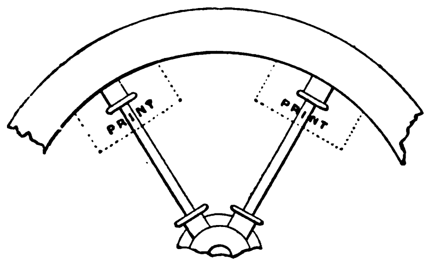


Fig. 90.

we shall make the rim in another way, though still without a complete pattern. We shall have no board, but a sweep of exactly the same section as the wheel rim, and a foot or two longer (according to the size of the wheel) than the sixth part of its circumference (Fig. 90). Exactly one-sixth part of the inner circumference of the wheel (=its radius) will be marked on the inner edge of the sweep, and on the centres so marked prints and half bosses for the reception of the arms will be fastened (Figs. 90, 91).

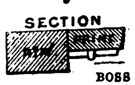


Fig. 91.

Then the sweep, with its bosses and prints, is rammed up in sand level with its top face, and withdrawn. It is then carried round exactly one-sixth of its circumference, and its right-hand print and boss is dropped into the impression just made by its left-hand print and boss. There the sweep is again rammed up, to be again withdrawn and removed, until the ring, with its six bosses and six prints, is completed. The reason why prints are used is obvious on a moment's consideration. The wheel being moulded in segments renders it impossible to ram up a top part in place, as in the case of a pattern, and, as a consequence, the only possible way of making the top half of the boss is by a core.

This core-box will consist of a rectangular frame, having one side sweeped to the inner curve of the rim, and a bottom board, on which will be fastened the half boss and print (Fig. 92, enlarged for distinctness). These must be exactly in the centre of the box, and of exactly the same shape and size as those which are fastened on the rectangular print; otherwise there will be overlapping of joints in the casting. In fact, it is usual to joint the two boss halves and turn them together; then, taking them apart, use one for the core-box, the other for the pattern. The print in the boss is of the same diameter as the wrought-iron arms, and that part of the arm which enters the boss is jagged or notched, in order that the cast-iron may embrace it the more securely.

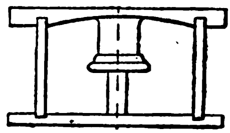


Fig. 92.

The mould for the rim having been completed, the arms are laid in the prints ready for their reception, the rectangular cores are laid over their ends (each in its print), and the entire ring is covered with a flat surface of loam or green sand. The rim is then cast and allowed to cool. When cool, but *not quite cold*, the boss will be cast on the opposite or central ends of the arms, which also will be jagged to prevent possible loosening.

The reason why the boss is cast on after the ring has cooled is that the contraction of the ring in cooling is so largely in excess of that of the boss, that the rigidity of the latter, supposing it were cast at the same time with the ring, by preventing the arms from coming inwards, would infalliby either bend the arms or fracture the rim. Hence the boss is always cast when the rim has nearly, but not quite, done contracting, there being, of course, a slight amount of shrinkage on the boss.

A complete pattern boss is wanted, jointed in the centre of the arm bosses in a direction parallel with the plane of the wheel. The boss mould also is made in halves, and usually dried.

CHAPTER XIII.

STRAP PULLEYS—METAL PATTERNS.

Curving of Pulley Arms.—Necessity of due Proportioning of Parts.—Rim.—Arms.—Boss.—Wood Patterns.—Iron Patterns: (I.) Made by Board and Core-box; (II.) By Sweep and Arm; (III.) By Ring and Set of Arms.—Split Pulleys.—Metal Patterns.—Why used.—Their Preparation.—Range of their Utility.

THE arms of pulleys, or of riggers (Fig. 93) as they are sometimes called, are usually curved, except in the case of those of very small diameter. This curving is considered essential in these light castings, lest the shrinkage of the boss, which remains hot longest after casting, should tear the too rigid arms asunder, either in the mould or at some subsequent period. Straight arms would be unyielding, while curved ones are somewhat analogous in character to a bent spring. For the same reason also the greatest care is necessary in properly proportioning the metal in the different parts—the boss, arms, and rim. To reduce the metal in the boss is the great essential. A heavy boss will infallibly break either the arm or the rim. If the rim is very rigid the arm will break, while if the arm be too strong the rim will break. In either case the mischief is due to the internal tension or stress set up through the contraction of the boss continuing after the rim and arms have cooled down and set. Hence, let the pulley be so proportioned that the boss shall contract very little after the other parts have cooled—so little that the moulder can counteract that small excess by opening the mould around it and allowing it to cool while the rim and arms still remain covered. Make the boss as light as possible consistently with safe working, and give the necessary strength for keying by adding a keyway boss (Fig. 93, *a*).

In proportioning pulleys, let the rim be from $\frac{3}{16}$ inch thick in small riggers to $\frac{1}{4}$ inch or $\frac{5}{16}$ inch in large ones, when turned. For pulleys running at a high speed give $\frac{1}{8}$ inch or $\frac{3}{16}$ inch rounding per foot width of surface; for those running at slow speeds, say, ⅜ inch of rounding per foot. This rounding must be omitted in the pattern, except where it happens to be parted in the centre, care being taken, however, to allow sufficient thickness of rim to permit of the casting being turned to this extent in the machine shop.

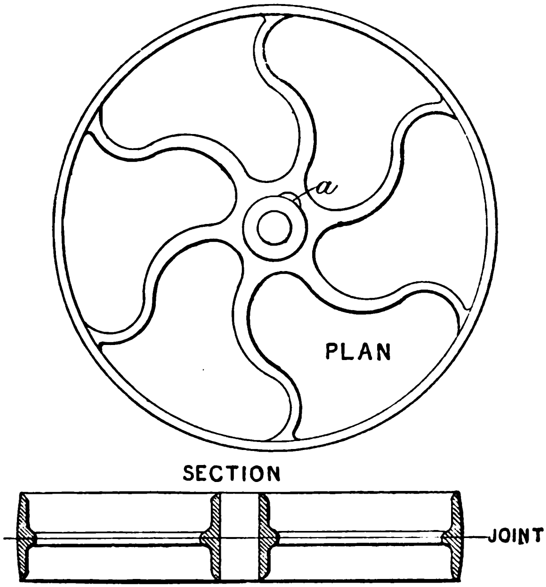


Fig. 93.

For the curves of the pulley arms set rules could be given; but for my part I prefer simply to line out roughly with a pencil an arm which has a graceful appearance, and then adapt radii to it. In giving to the arms their *cross sections* a trained eye is almost or quite as safe as rules; but in the absence of experience the following rule gives correct results f o pulleys doing ordinary work:—

$$\sqrt[3]{b = \frac{d \times w}{n \times 8}}$$

where b = breadth of arm at point,
d = diam. of pulley in inches,
w = breadth of rim in inches,
n = number of arms.

Thus a pulley 4 feet in diameter by 9 inches wide, having six arms, would have an arm 2 inches wide at the point. Near the boss the arm should be one-third wider than it is at the rim. Its section should be elliptical, and its thickness equal to half its width. If made thinner, the strength must be made up by cross ribs running down its centre (Fig 94).

The thickness of metal around the hole or eye is variable, depending upon the size of the shaft and the diameter of the rigger. A rigger on a small shaft will require less metal than the same rigger on a large shaft, because the torsional strain is less in the former case than in the latter. A large rigger will require more metal than a small one, because both torsional and centrifugal force will be greater in the case of the large than of the small one. Up to 2 inches or 3 inches in bore the boss is generally made twice the diameter of the shaft; over 2 inches or 3 inches a less ratio obtains. Practical men usually judge by the eye in proportioning a boss. A formula which gives a good boss is this:—

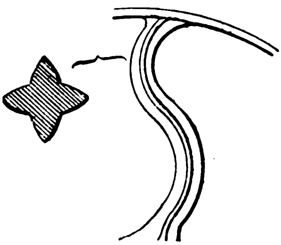


Fig. 94.

$$D + d + 5 = t$$

Where D = diam. of pulley in feet,

d = diam. of shaft in inches,

t = thickness in metal in boss in *eighths of an inch.*

The length of boss may be two-thirds the breadth of pulley, except in the case of fast-and-loose pulleys, where they should be a trifle longer than the breadth of rim, $\frac{1}{8}$ inch or thereabout. The keyway boss should be as thick as the depth of keyway, and embrace one-sixth of the circumference of the main boss.

Small strap pulleys are sometimes made from a complete pattern of hard wood, in which the rim is built up in segments, and the arms let in when the building-up process has reached to the centre. Owing, however, to the extreme lightness of these pulleys, wooden patterns are too flimsy and fragile for those of larger diameter or those intended for repeated use. Hence in usual practice we discard wooden patterns, and resort to as many as three other different methods of making pulley castings. The first and least commendable method is that described in connection with the flywheel with cast-iron arms in the previous chapter, viz. that in which a board and core-box is used. Except for a makeshift and temporary job this is not to be recommended, not even for large pulleys, much less for those of moderate size. An iron pattern is far preferable, and is essential where there is a repetition of castings.

The iron pattern itself will be made either from a rough wooden pattern, just strong enough to hold together for the one moulding, or from a previously existing casting, or it may be struck up. If deep, it ought to be jointed in the centre of the arms, to afford better facilities for moulding (Fig. 93, section). An iron pattern in halves can be made very readily thus: a sweep, half the total depth of the rim, can be worked round to form the ring, and a single arm and boss, jointed down its centre, can be rammed up six successive times to form the six arms of the pulley. Two separate halves can be made in this manner, and be jointed afterwards to form a complete pattern. A pattern thus made must be dowelled, turned, and filed in the fitting-shop, and then varnished or beeswaxed, warm, before it is ready for the foundry. This is somewhat costly, but the first expense over it is, accidents excepted, imperishable, and free from the defects to which wooden patterns are liable, as warping, shrinking, and such like.

A third method is to have an iron pattern still, but in a modified fashion. There will be an iron ring (Fig. 95) repre-

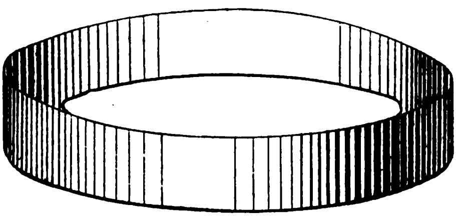


Fig. 95.

senting the pulley rim, turned inside and outside, but wide enough to embrace the widest pulley that may reasonably be expected to occur—say 12 inches to 15 inches. This will be made from a sweep in the first place. Also a complete set of arms distinct from the rim, with a hole in their centre for the reception of separate bosses of any required diameter (Fig. 96). The advantage of this latter method is that pulleys may be made off such a pattern of different widths, and with bosses varying in size to suit different-sized shafts.

These, of course, are expensive, but are everlasting, and extremely convenient for making pulleys of variable widths and bores. The inconvenience caused by the absence of a joint is got over by the moulder thus: He does not ram up the top box over the rim and arms, as in an ordinary pattern;

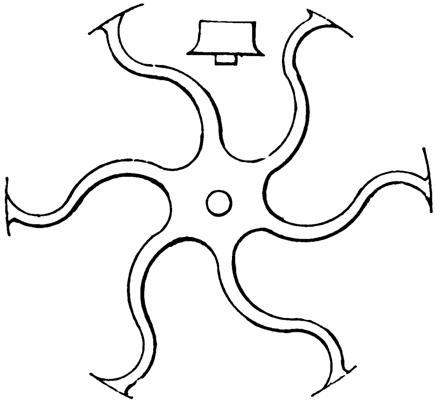


Fig. 96.

but using the rim and arms as a *core-box*, makes and lifts away two cores, top and bottom, to be replaced after the outside of the rim is rammed up. The necessary depth of rim is given by a strickle working down from the top edge of the rim.

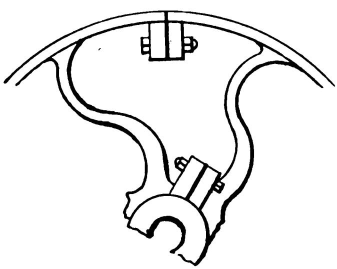


Fig. 97.

Pulleys are often split for the same reasons that cog-wheels are split, when they are to occupy some intermediate portion of a shaft (Fig. 97). The same process is adopted as in cogwheels (Chapter VII., p. 47), blocks and prints and splitting plate pattern being required. The curving of the arms gives a rather unsightly appearance to the lugs on the boss, but it cannot be avoided, and is a matter of no real consequence.

Metal Patterns.—A few remarks on these, suggested by the subject now discussed, may fitly close this chapter. Patterns are very often made of metal. They are so made when, from the flimsy character of the work, a wood pattern would get out of shape or become broken to pieces, or where the number of castings required is so great that a wooden pattern would not last long enough to mould the total quantity. In the former category may be classed all kinds of light and ornamental work; in the latter, almost anything of moderate weight.

If we make a pattern of wood from which to mould a metal pattern, we do not bestow anything like that amount of labour upon it which we should devote to one for standard use. We should neither build it up with a view to strength and durability, nor should we finish it so neatly. It will be made so that it might be moulded once, after which it is useless. But we bestow all our care on the metal pattern. We should turn it where circular, and plane, or file, or grind portions which could not be turned. If made of brass, nothing further is requisite; but if of iron it must be coated with some preservative against rust. Warm the metal and rub it over with a rag dipped in melted beeswax. This forms a glossy skin, and allows the metal to leave the sand readily; or varnishing with shellac varnish also answers very well. But to insure the adherence of the varnish on bright work it is necessary to rust the metal first. Wet it with a solution of salammoniac, allow it to dry, then glasspaper and varnish.

In making a wood pattern for a metal one *double* contraction must be allowed, since there will be the contraction of the metal pattern itself besides that of the casting to be allowed for.

The use of metal for patterns is not, however, restricted to iron and brass. Sometimes we want a curved casting, and various reasons would concur to render the working of wood patterns unadvisable—the attendant expense, the weakness of cross grain, the difficulty of marking out, and such like. Then we make a straight wooden pattern, cast it in lead, and bend it to shape afterwards. From this a more rigid iron pattern can be made if required.

Lastly, wood patterns will often have metal parts. Thus the bearing faces for the shoulders of brasses when skewered on are usually made in metal, since in wood they would become broken in consequence of their fragility. The letters for nameplates also are cast in metal and fastened to a wood plate, and we shall find as we go along many cases in which the pattern-maker resorts to the use of metal as being preferable to that of wood.

CHAPTER XIV.

MISCELLANEOUS ENGINE WORK.

Eccentric Sheaves.—Straps.—Slide-valves.—Guides.—Cross-heads.

BEYOND the cylinder pattern, the pattern of its bed, and the flywheel, there is nothing in engine work difficult or intricate from the pattern-maker's point of view. Hence we shall run rapidly through the only items that call for remark in connection with an ordinary engine, comprising them in the compass of a single chapter.

Double eccentric sheaves, forward and backward, are cast together. The pattern itself consists simply of two plain discs dowelled together, the grooves being turned out in the casting. But the dowelling together of the discs requires care. Proceed thus:—Say we have an engine with $\frac{3}{8}$-inch lap, $\frac{1}{16}$-lead, and $2\frac{1}{4}$-inches throw of sheave. Strike a circle $2\frac{1}{4}$ inches diameter on the centre of the crank shaft, and draw a line through its centre (Fig. 98). At a distance away from this

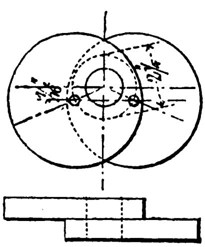


Fig. 98.

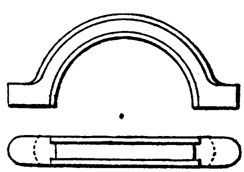


Fig. 99.

line = $\frac{7}{16}$ = lap and lead, and parallel with it draw another line. The two points where this second line cuts the $2\frac{1}{4}$-inch circle will be the centres of the two sheaves, forward and backward respectively. Strike the circles representing their diameters; lay one disc upon the drawing on its proper circle, and dowel the other upon it perpendicularly over its circle, adjusting it with set square. Put the print for the shaft-hole on the pattern for one pair of sheaves first, say the right hand. Cast one off, then remove the print to the other centre for the left-hand pair.

As small eccentric straps (Fig. 99) are usually made in gunmetal, the grooves in many instances are cut out in the pattern. The neatest way to get out the inside of the strap with its grooves is to turn it; but as an allowance for facing is given in the joint, which makes the pattern $\frac{1}{16}$ inch more than a half circle, the straps are turned a half at a time, a false block being screwed on the face plate to complete the circle—its face standing $\frac{1}{16}$ inch back from the centre line—while the two half straps are being turned in succession. The outside portion, with its lugs for bolting together, is worked by hand, away from the lathe. The lug or facing for eccentric-rod, and the oil-cup boss (not shown) are put on separately. Straps are moulded at pleasure either on their sides or edges, the latter giving, as a rule, the cleanest metal.

Slide-valves of the D-shaped type are those most commonly used. Ordinary valves are too simple to cause any trouble to the pattern-maker, accuracy being the important condition.

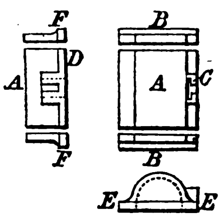


Fig. 100.

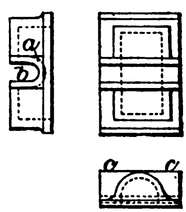


Fig. 101.

The usual D-shaped valve, as the type of the class, is the only one therefore that calls for special notice. A glance at the sketch (Fig. 100) will indicate the way in which it is made. The block (Fig. 100, A) forming the inner portion of the valve is planed to width, and marked out and worked through with gouge and chisel. The sides, B, B, are also worked to shape and then fastened to the block. The piece, C, for the reception of the valve-rod head is fastened in place, and a print for the nut core bradded on. An allowance of $\frac{1}{8}$ inch is made on the face D for planing, and the same at ends, E, E, for accurate cut-off; a similar allowance also at sides, F, F for close fitting into the steam-chest.

A D-valve, like Fig. 101, is made in a similar way, except that, after the D shape is worked, a half-round piece, *a*, is glued within, and when dry the recess, *b*, for the valve-rod is worked on the outside, the pieces, *c*, *c*, being fitted and glued round the curve to form the flat edges and ends of the groove.

A valve, like Fig. 102, is made in three pieces, as in the first instance, or cut out of a solid piece of stuff; but the outside, instead of being worked half-round, is partly turned and partly dressed off by hand. Allowance for turning is made also where the eye of the valve-rod slips over.

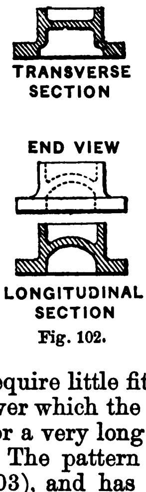


Fig. 102.

An ordinary steam-chest calls for no special remark, and of a double-flanged one it is sufficient to note that the bottom flange must be left loose from the body. Patterns also for plain, flat guide-bars are made just like their castings, so we say nothing about them. Instead, however, of the old guide-bars, circular guides, bored to receive a circular cross-head, are coming into common use. They are cast in a piece with the cylinder cover, have a massive appearance, require little fitting, and owing to the large extent of surface over which the friction of the cross-head is distributed, wear for a very long time.

The pattern is made in halves, jointed longitudinally (Fig. 103), and has a print at each end. The open parts of the guide (Fig. 103 C, C) are cut on the pattern as far inward as the diameter which corresponds with the body core of the guide (Fig. 103), section, *d*, *d*.

For the core, a box is necessary, owing to the existence of the facings, *e*, *e*, for the cross-head, which will not allow of its being struck up. The box is dowelled in halves, and worked with templets. Fig. 104 shows one half, looking into it from the joint.

The cross-head, or head of the piston-rod, is of the shape indicated in Fig. 105, when flat guides are used, and like Fig. 106 when it works in a circular guide. In the former case the pattern would be jointed and cut out to the shape of the casting, the holes, if large, being cored with a parallel print bridging over between the sides. In the latter form

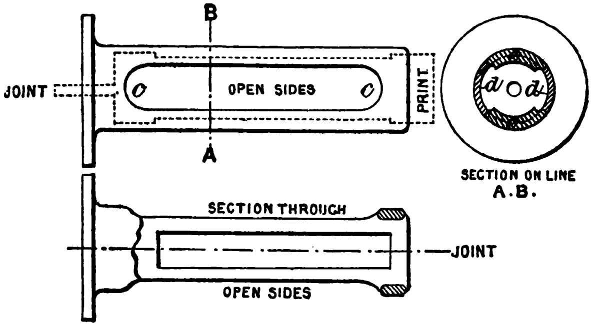


Fig. 103.

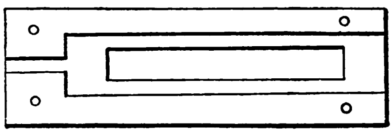


Fig. 104.

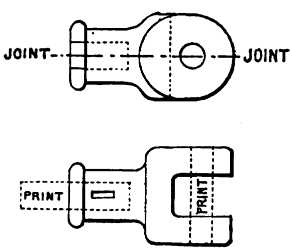


Fig. 105.

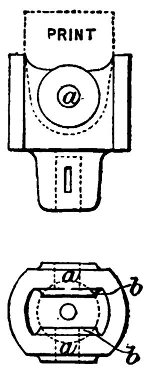


Fig. 106.

(Fig. 106) the inside is taken out with a core, the pattern moulding either on its side or on its end, and requiring no joint. In either case the core-box will be jointed longitudinally, and the holes, *a*, *a*, will be cut out in top and bottom boards dowelled on the box body, which boards will also carry the top and bottom facing bosses, *b*, *b*.

Cranks, brasses, pistons and their rings, slipper blocks, governor castings, except when there is something special in their construction, are too simple to need description from the pattern-maker's point of view; so with this chapter we close our remarks on engine work and pass to other subjects.

CHAPTER XV.

SHEAVE-WHEELS.

Modified Provisions for the Reception of the Chain.—Patterns.—Mode of Jointing.—Built-up Patterns.—Templets.—Sheave-wheels with Cast Arms.—With Wrought-iron Arms.—Core-box for Rim-cores.—Central Boss.—Sheave-wheels made entirely with Cores.—Their Boxes.—Recessed Chain-wheels.—Rope-wheels.—Wave-wheels.—Projection of the "Wave."—Sprocket-wheels.—Wrought and Cast Fingers.

A SHEAVE-WHEEL is a wheel with a rim grooved or hollowed out for the reception of a chain or rope. We take the chain-wheels first in order.

In a plain sheave the chain lies in its groove in the direction shown in Fig. 107. But a chain when in motion is always apt to twist, and when, as in hoisting machinery, a heavy load is directly dependent from it, a sudden return to its normal position will be accompanied by a jerk, and, as a consequence, a considerable extra strain will be put upon it at once. Hence it is customary where the wheel is immediately over the load dependent from the chain, and not merely acting as a carrier

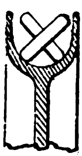


Fig. 107.

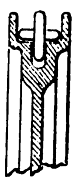


Fig. 108.

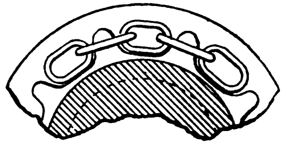


Fig. 109.

or support, to use, instead of a smooth sheave, one grooved out, so that the chain links may lie successively parallel with, and at right-angles to, its axis (Fig. 108). Further, in the differential pulley-block, and in all cases where the wheel has to draw the chain along, the friction of the simple groove would not be sufficient to overcome the resistance of the load, and then the wheel is recessed at regular intervals to receive the alternating flat links (Fig. 109).

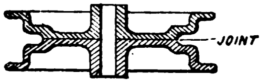


Fig. 110.

These wheels, if small, will have plated centres (Fig. 110); if moderately large, cast-iron arms with transverse ribs (Fig. 111); if very large, wrought-iron arms, which will be usually strutted (Fig. 112).

If a whole pattern—that is, one not cored out round the

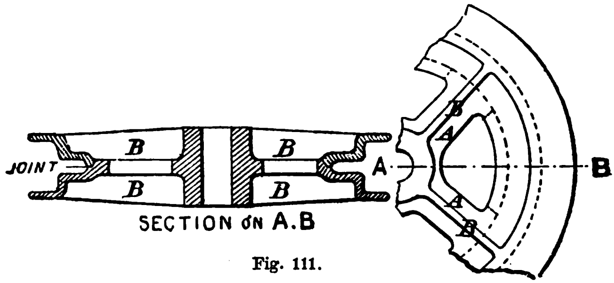


Fig. 111.

rim—be made for a sheave-wheel, it must be jointed in the centre, because the groove for the chain will have to be

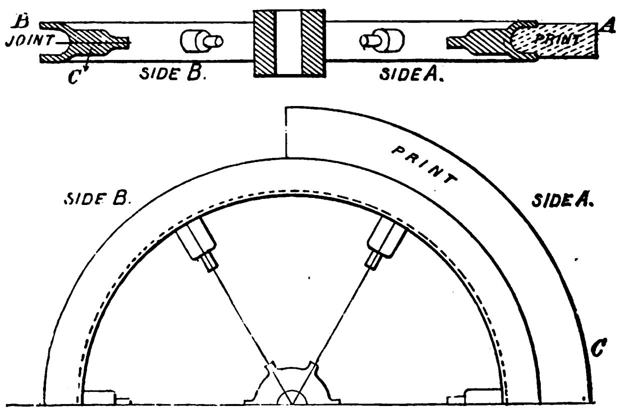


Fig. 112.

lifted away as a middle ring of sand. Whether it be a wheel with arms, or one solid plated, the joint may be made either through the exact centre of the arms or of the plate (Fig. 110), or along their upper faces (Fig. 111), the ring alone in the upper portion being left loose. When, however, the rim is *cored* out, both rim and arms (or plate) and circular print are all made fast together (Fig. 112, side A).

Sheave-wheels are used generally as standard patterns, therefore it is well to take especial care in their construction. Glue them up in courses of segments, using thin stuff—say ½-inch or ⅝-inch—and good glue. Also peg each course with small pegs. Never mind about the pegs coming through here and there. If the wheel is plated, have at least two courses of segments in the plate, unless it be small—say less than a foot in diameter, in which case a piece of very dry solid stuff will do.

The wheel, when glued up, must be turned with templets made from the sectional drawing. Fig. 113 shows the half-pattern in section, and the method of cutting the templets for its inner and outer portions respectively. The centre hole for the studs of the bosses will serve for rechucking the pattern when one face has been turned. We prefer having a central stud hole for the reception of separate bosses, to making the bosses an integral part of the pattern, because we can then use the pulley for different sized shafts by simply making fresh bosses of the required diameters.

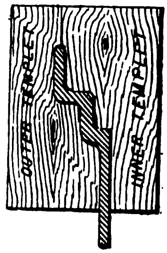
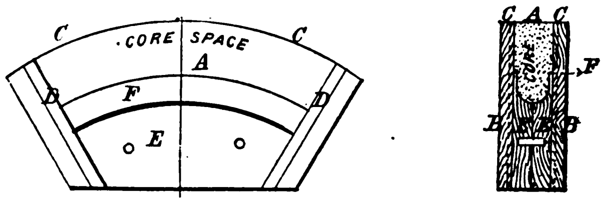


Fig. 113.

But if instead of a wheel with a plated centre we have one with arms, we shall make those arms as for a spur-wheel (Chapter III., p. 25), by locking them together and letting them into the rim (Fig. 111, A, A), there gluing and bradding them. Similarly bosses and cross-ribs (B, B, B, B), having a slight amount of taper, will be fastened to these flat arms. Hollows may be put in or omitted at discretion.

Next take a large pulley with wrought-iron arms (Fig. 112). In some cases it will be advisable to use a complete pattern on account of the number of castings demanded. The ring could then be made in the usual way by building up in two halves and jointing (Fig. 112, side marked B). The bosses and their prints (C) on the inside of the ring would be jointed also. This will answer very well where the wheel is of stout proportions. But if it were light in section, such a pattern would not bear foundry usage very long, and an iron pattern would be advisable. But another method would be to build up a solid ring with a broad print (Fig. 112, side marked A), and to take out the groove with segmental cores — say ten or a dozen to the circle (Fig. 114, A). The advantage here would be that without making an iron pattern we should still have a rigid rim, not liable to become rammed out of truth—a matter of importance in a wheel of any kind. And further, although there is the additional expense involved in the making of the cores, we also save as a set-off against this the trouble of the middle-part box, since, instead of the joint on top and bottom, we want one joint only at the top face of the print.

The core-box will be made thus:—Two sides will be prepared (Fig. 114, B, B). Their outer edges (C, C) will be worked to the same radius as the outer edge of the print C, in Fig. 112. Their inner edges—straight—will extend about a couple



SECTION.

Fig. 114.

of inches below the line which represents the bottom of the wheel groove. In these sides cut grooves (D, D) $\frac{1}{4}$ inch deep, radial from the centre of the wheel, and at a distance apart equal to the intended length of the segment of core; a sixth, tenth, or twelfth of the circle, as the case may be. Into these grooves drop distance pieces of the width necessary to keep the sides at their proper distance apart—that is, equal to the thickness of the print. Then fit a couple of blocks (E, E) between these sides and ends, parted longitudinally down the centre of the box and dowelled. Work their edges (F) to the same radius as the rim of the wheel, then mark on their ends the rim section. Cut out the groove thus marked with templet very truly, so that when the cores are made and laid end to end they shall correspond neatly, and not show a lapped joint in the casting. When worked, replace the pieces in position, and screw them one to each side of the box. It only remains now to put on the bosses for the arms, and to make the central boss with its prints precisely as in the case of a flywheel with wrought-iron arms (Chapter XII., p. 83).

When the arms are strutted to give rigidity to the wheel, the bosses on the rim have to be bevelled alternately in opposite directions, and the prints on the central boss bevelled in like manner. These latter, too, in a strutted wheel should be *pocket* prints, and not round ones; for round prints would necessitate two joints in the body of the boss, coinciding with the centres of the prints, while with pocket prints the joint on the top face of the boss is alone required.

There is yet a common way of making a large sheave-wheel without a pattern at all. A glance at the sketch (Fig. 115), will indicate the method to which I allude. The light portion is the wheel rim in section—the dotted parts indicate two cores, one outer (A), one inner (B), forming outside and inside of rim respectively. It is seen that these cores are jointed at B, B. Of course the joint must be a curved one, both cores being worked to the same radius. The outer edges of the cores (C, C) need not be curved at all, because they form no part of the wheel. Give sufficient sand there, say two or three inches in the narrowest part, and some lesser amount, say 1 inch to 1½ inch, at the sides.

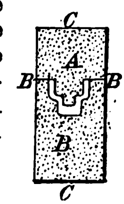


Fig. 115.

To make these boxes:—First frame sides and ends together for each respectively. Their ends must converge to the wheel centre, and must either cut through the centre of

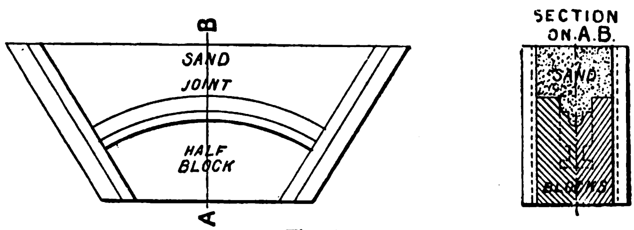


Fig. 116.

an arm boss or midway between two bosses. Thus, if the wheel have eight arms, there must be either eight or sixteen cores. Assuming there are eight cores, we have a half-boss at each end of the inside box. The boxes must be equal to each other in width, which will include the width of the rim and of the two sand joints (B, B, Fig. 115). Then blocks will be fitted between these boxes, as in the last example; those forming the wheel *groove* will be worked out by templet to the shape indicated in Fig. 116, and those forming the inside portion of the rim will be worked like Fig. 117.* It is not necessary to fasten either of these blocks in place, for if their flat bottom edges are planed while in position level with the bottom edges of their boxes, they cannot shift when being rammed on a level core-bench or bottom board. The half-boss fastened on each end of the inner box, together with its arm print reaching to the termination of the sand (Fig. 117),

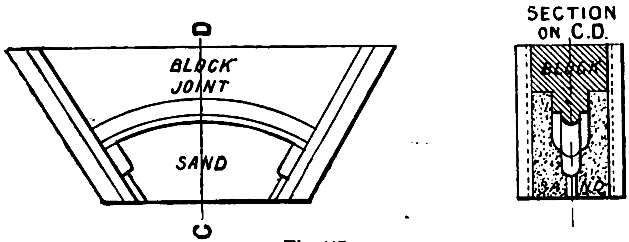


Fig. 117.

will complete the pattern-maker's part of the business. The moulder simply guided by a line struck on a level sand bed, lays a ring of inner cores in place, brings the outer cores to abut against these by the circular joint, thrusts the wrought-iron arms through their prints into the bosses, rams sand around the outside and the inside of the cores, and then casts the ring. When nearly cool the boss is cast around the opposite ends of the arms, as in the flywheel alluded to in Chapter XII., p. 83.

A sheave-wheel recessed for alternate links of a chain can be made by pattern or core-box. It requires almost as much care in pitching out as a spur-wheel, because if there is a slight initial error in the pitch, that error increases with each successive link. Thus, when we commence to lay the chain in, suppose we find the recesses are $\frac{1}{16}$ inch too far apart, the error will not remain at $\frac{1}{16}$ inch all the way round the ring, but will be $\frac{1}{8}$ inch in the third recess, $\frac{3}{16}$ inch in the fourth, $\frac{1}{4}$ inch in the fifth, and so on, so that by the time we had got half-way round a large wheel no reasonable amount of clear-

* Fig. 117 is drawn to show the position of the core relatively to Fig. 116, the box, of course, being turned the other way up for ramming.

ance between the links and their recesses would prevent the chain from riding out of place. In pattern wheels we can always insure accuracy by roughing out the recesses on a slightly larger diameter than we deem necessary; and then, trying the chain in, gradually reduce the wheel until it fits neatly all round. But when a wheel is made with cores we have not this chance, and then we must take especial care in getting the exact pitch of the links first of all, and in transferring that pitch to the drawing from which the core-box is to be made. Hence we must measure off the total length of a definite number of links, and divide that total length by the number of links measured; this average will be the pitch of the chain, which we forthwith transfer to our drawing-board. Working thus we shall not find our wheel at fault after it is cast. Some clearance is allowed sideways and endways for the links, say $\frac{1}{8}$ inch all round, and the recesses are worked out of the solid with gouge and chisel, in pattern and core-box alike.

In all other respects the directions we have given for the making of plain sheave-wheels will apply to these as well.

A common rope-wheel is similar to a plain sheave-wheel, with the exception that its inner sides are inclined at a somewhat acute angle in order to bite the rope in the bottom of the groove. This object is sometimes also assisted by little semicircular bits, or nibs, pitched at regular intervals, and standing a little above the groove. Be the rope-wheels large or small, the same methods of making the patterns will be adopted as in the previous examples.

But there is a modification of this form which is sometimes used, and which is somewhat puzzling at first sight—I mean the wave-wheel form. It is a rope-wheel, in which the rim, instead of continuing in one circular plane, as in ordinary wheels, is bent or *waved* in serpentine fashion, the object being, of course, to increase the friction of the rope and thus prevent it slipping.

This is a device which is seldom adopted in small wheels, and therefore it is so seldom necessary that a complete pattern should be made thus that we shall only consider it as applying to a wheel made entirely with cores. The remarks we previously made as to the method of procedure to be adopted in the preparation of the core-boxes will be applicable here until we arrive at the working out of the internal blocks. Then our difficulty will be to insure that the metal in the rim shall be of uniform thickness throughout. If we go working away at the curves at random, trusting only to the eye for accurate results, we shall probably find a variation of ⅛ or ¼ inch in the thicknesses of different portions of the castings.

So we work in the following way:—Draw in elevation a

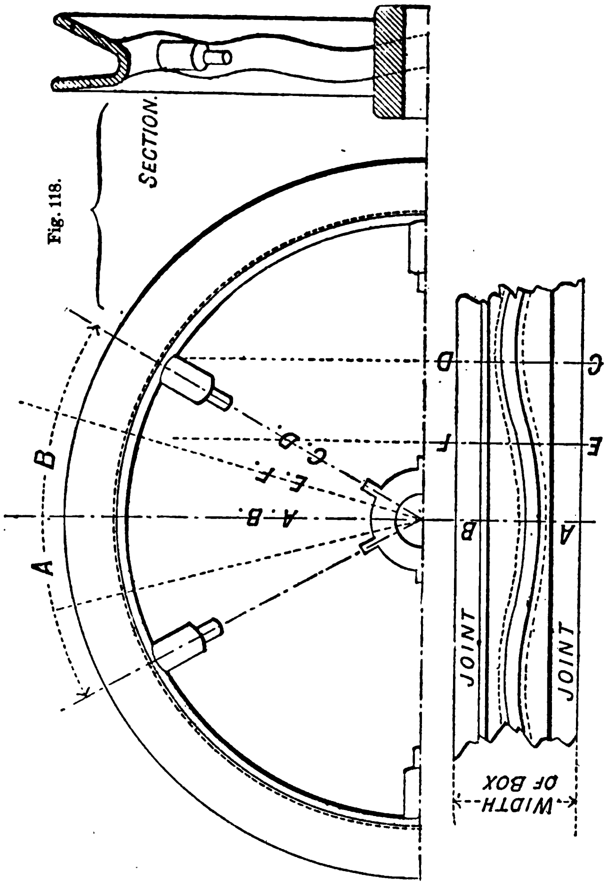


Fig. 118.

Fig. 119.

segment of the wheel, equal in length to the intended length of the cores (Fig 118, A, B). Draw also lines on this view converging to the wheel centre from the pitch distance of the wave, viz. at these points where it attains its greatest deviation from the plane of the wheel, A B, C D. Draw a portion of the rim with the intended width of the core-box besides in plan (Fig 119), and carry the lines representing the pitch across it. At these points draw sections of the rim in its extreme positions *relative to the sides of the boxes* (Fig 120). Between these extreme deviations of the wave draw other lines at

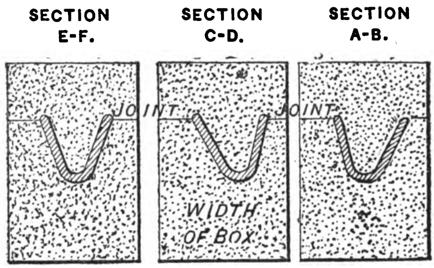


Fig. 120.

pleasure (not shown on engraving), projecting these to the plan, and drawing corresponding sections also in relation to the sides of the core-boxes. Then making templets to the inside and the outside of the rim, all we have to do is to work narrow portions of the rim at the distances from the edge indicated in the sections, and to shape the intermediate portions with gouge and chisel as regularly as possible. If this is done carefully there will be no appreciable difference in the thickness of different portions of the wheel rim when cast.

The last form of chain-wheel we shall describe is that known as the *sprocket* wheel (Fig. 121). It is a form which is in very general use for the transference of motive power by means of a flat link or "pitch chain." Like the chain-wheels, these require to be pitched out very carefully, else the pitch-chain would ride on the projections, or "sprockets," instead of dropping over them.

These wheels are made in two forms, the first like the Fig. 121, where the sprockets are made of wrought-iron and cast in the wheel body; the second like Fig 122, in which the sprockets are a portion of the casting. In the former case they are dropped into prints, whose edges are their exact counterparts; in the latter, the pattern and casting are precisely similar.

In these castings the links must fit the places prepared for their reception so nicely that it is sometimes necessary in a large wheel to throw away the first cast and make a slight alteration in the pattern, a variation in the anticipated amount of contraction being sufficient to cause $\frac{1}{8}$ inch or $\frac{1}{4}$ inch of error in the semicircumference. The wheel might be saved in such

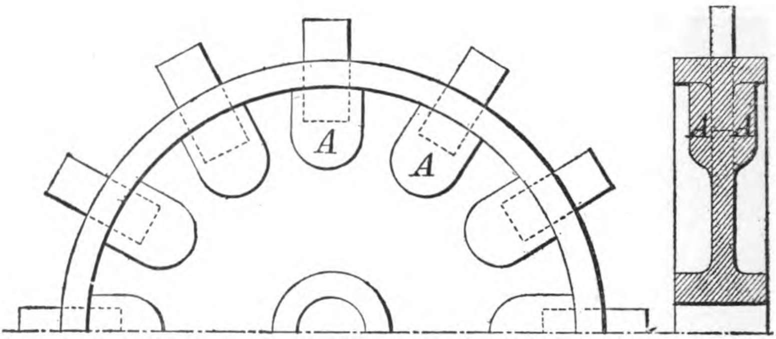


Fig. 121.

a case by filing a lot of clearance in the sprockets; but such a practice is not to be commended. The accuracy of a small casting can be depended on.

After what has been said about the building up of wheels, special remark is scarcely necessary in reference to these last-named. Note, however, that a built-up plate made in two or three thicknesses or segments is better than a single solid

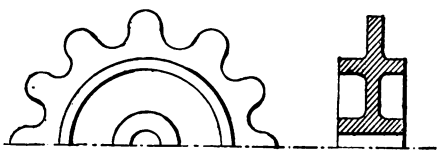


Fig. 122.

piece of stuff in which the sprockets are cut out, because short grain and shrinkage are both avoided thereby. On this plate the two portions of the rim are built with segments as usual.

The prints for wrought-iron sprockets should be pocket prints, to be stopped over after the sprockets are placed in the mould.

In Fig. 121, A A, are the boss thicknesses around the wrought-iron sprockets.

CHAPTER XVI.

COLUMNS AND PIPES.

Jointing of Columns and Pipes.—Lagging up.—Turning.—The Use of a Steady.—End Flanges.—Body Flanges.—Socket-pipes.—Putting Holes in Flanges.—Loam-pipes.—Fitting Branches.—Throat Core-boxes.

MAKE it a rule to joint all columns and pipes, whether they be large or small. Jointing the pattern prevents the tearing away of the upper half of the mould, and the joint forms a convenient basis for the marking of centre and parallel lines, the setting square of blocks, facings, flanges, bosses, &c. Pipes and columns up to 7 or 8 inches in diameter will be made of solid stuff; if they exceed those dimensions they should be "lagged up" (Fig. 68, p. 61). The transverse blocks or bars upon which the lagging is to be laid may be about 12 inches or 15 inches apart, so that in a long pipe or column there may be as many as a dozen of transverse blocks, and each bar should have a dowel in the centre. The number of pieces of lagging which form the circle will vary with the diameter of the pipe or column. An 8-inch pipe may have eight strips to the circle, while a column of 16 inches or 18 inches diameter may have a dozen. Fit the strips and glue successively in the manner described when treating of engine cylinders,* the only difference being that a long joint is not made to fit close so readily as a short one, and may require to be chalked and tried in place repeatedly before a fit is obtained. When built up, secure the two halves of the pattern with centre-plates (Fig. 212, p. 160), and put into the lathe. If the pipe be long, staple the joint at intervals before attempting to turn. Do not turn any one portion to finished sizes immediately, but rough the whole pipe down from end to end first. If other work can be prepared in the

* Chapter IX., p. 60.

interval, it is even better to let it remain thus roughed down for a few hours before finishing than to finish at once. The reason is, that all timber, whether well seasoned or not, has a tendency to spring, and will in most cases buckle more or less out of its original shape when newly-cut grain is exposed to the air. For this reason a careful workman, when beginning a lengthy job, always "gets out" as much stuff as he can see his way clear to prepare, and "jacks" it all over before planing or turning any one portion to its finished dimensions.

If the column or pipe be of small diameter relatively to its length, it will vibrate or "wobble," to use a workman's term, in the lathe, so that to turn it true will be impossible. Make a steady, shaped roughly to fit the bed of the lathe and to take the diameter of the pipe. The sketch, Fig. 123,

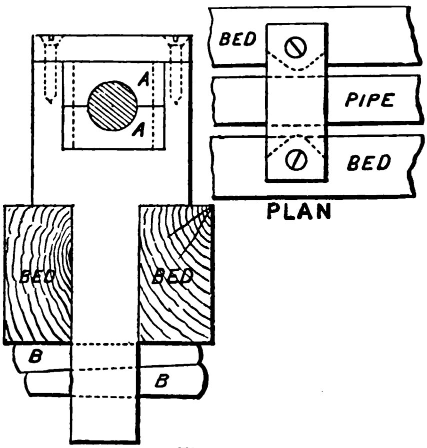


Fig. 123.

shows the best way to make a steady. By means of the sliding blocks, A, A, replaceable at pleasure with blocks of any other dimensions within the limits of the Vee'd portion of the steady, we can make it a standard tool for pipes of various dimensions. Wedge-shaped cottars, B, B, passing through the shank, will hold it firmly in position on the bed. A lubricant must be applied where the pipe runs in the steady, else much heat will be developed, and an excessive amount of friction be set up. Soft soap, or soft soap mixed with blacklead, are good lubricants.

It will facilitate the operation of turning if, in a long pipe, after having reduced the two ends to the required diameter, we plane a straight flat along the pipe from one of the finished ends to the other. We can then see at a glance, when working at any portion of the pipe, whether we are nearly or quite down to the size, without having recourse to calipers and straightedge continually.

Flanges, round, square, or of other shapes, socketed or spigoted ends, belts, mouldings, &c., will be required for pipes and columns. If the pipe is to be flanged, the flanges will be made distinct from the body of the pattern. A flange will be made in halves, dowelled together; and where it is put on at the end of a pipe, the hole must be made of such a size that it

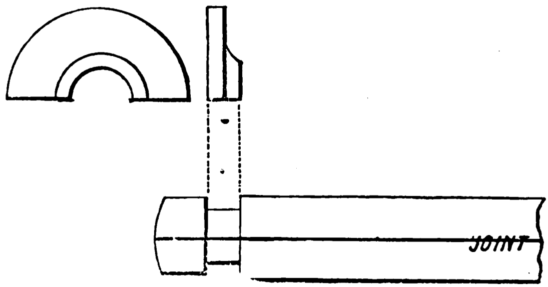


Fig. 124.

shall drop into a groove somewhat smaller in diameter than the print, to keep it steady. If the print at the end of the pipe is, say, 4 inches, the groove may be 3½ inches in diameter (Fig. 124). The stuff should be got out thicker than the actual thickness of the flange, to allow of a small radius or hollow being turned out at the back. If the casting is to be faced, ⅛ inch must be added to the thickness on the front side of the flange on that account. If the flange is to go on some part of the pipe intermediate from the ends, it is usual to turn it as a "body flange"—viz. a flange having a hole of the same diameter as the *outside* of the pipe, Fig. 125. The flange can then be slid along and screwed to any desired position, and the casting can be "stopped off"* to the corresponding length. In body flanges the hollow on the back is usually omitted, being left for the moulder to rub in sand.

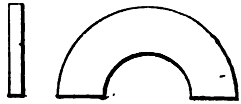


Fig. 125.

* Chapter XXI., p. 150.

For socket and spigot pipes, or faucet and spigot, as they are also called, the pattern may have blocks glued upon it just where the socket is required, large enough to bring it up to the proper size, and long enough to include the socket print, which, of course, will be larger than the outside of the pipe by the necessary allowance for "caulking." This method of blocking up the pattern with a permanent socket, though proper enough for standard work, would be absurd in a jobbing shop where pipes of all lengths and of both kinds—flange and socket—are made from a single 9-feet length of pattern. We must have the socket, like the body flange, a thing quite distinct from the pattern, to be screwed on anywhere or removed at pleasure. The most convenient form is an iron pattern socket in halves, fitting over the body of the pipe, and cast very thin to reduce its weight. A single screw run in from the top holds it in position (Fig. 126); dotted lines indicate how the socket is lightened out.* For the spigot a bead of lead may be cast, bent round, and tacked to the pattern, or, if for permanent use, it may be turned out of the solid.

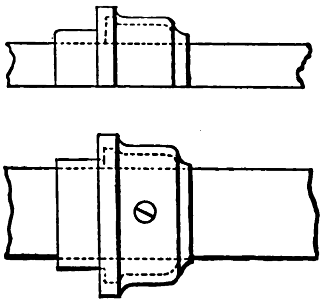


Fig. 126.

When round or square holes are cast in flanges, they should be put in by templet; in this case a piece of thin wood cut to the shape of a half flange and having slot holes cut out, the termination of those holes giving size and position of cores.

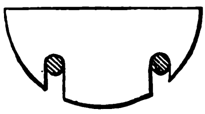


Fig. 127.

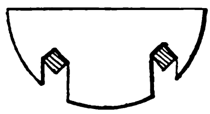


Fig. 128

The cores, rubbed to the thickness of flanges, are thrust into position by the templet, and the slight friction of their faces against the faces of the mould is sufficient to retain them in place during the inflow of the metal. Fig. 127 shows a templet flange for round, Fig. 128, one for square holes.

* For proportions of sockets and flanges, see Appendix, p. 257.

Pipe patterns from which a large number of castings are required are always made in wood or (where the quantity is very large) in iron. Yet we sometimes have pipes of a large size to make where the number of castings is not sufficient to pay for the cost of a pattern. In that case we make a loam pattern. That is a different thing from a loam mould In the latter case our boards are made to strike the actual *mould* (Chap. X.). In the former, the boards strike up the *pattern* from which the mould is to be made. The flanges will not be struck up, but made in wood, unless, indeed, they happen to project but a short distance from the pipe body. Mouldings and sockets, however, will be struck as part of the loam pattern. The annexed figures (129) will

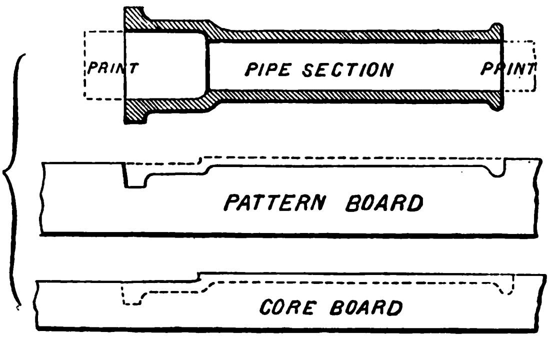
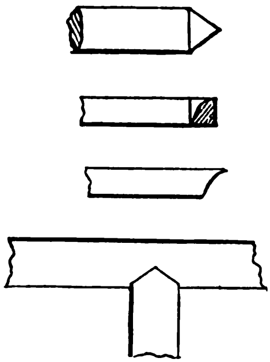


Fig. 129.

sufficiently illustrate the way in which a loam pattern and its core are struck up, without verbal explanation. We shall return to the subject of loam patterns again in connection with some more elaborate forms of work. See Chap. XXI., p. 145.

Branch pipes, fitted to a main piece of pipe, might have their ends struck out geometrically; but we can always, or almost always, chalk the main pipe and cut the branch to a fit in less time than would be occupied in striking the necessary lines. Where branch and pipe, however, are of the same diameter, there is a ready and simple method of insuring a fit at once. Having marked in the joint of the branch the line where it is intended to abut the edge of the pipe (Fig. 130), on this, as a base line, construct a triangle, whose sides shall be inclined towards it at an angle of 45°, meeting consequently and forming the apex at the centre line of the pipe. Cut to these lines at right angles with the joint (Fig. 131).



Figs. 130, 131, 132.

Where the cut faces intersect the circumference of the branch, a curve will result, which, if worked to, will insure the required fit without further trouble (Fig. 132).

Fig. 133 shows a tee pipe, or tee piece, made in the usual way, with a wide throat at the point of junction, for the purpose of allowing freedom of water way, and diminishing friction. Here a special core-box (Fig. 134) is advisable, to get the throat of the shape corresponding with the pipe. The core for the pipe, being plain and circular, can be struck up separately, and the branch core abutted against it in the mould. These throat

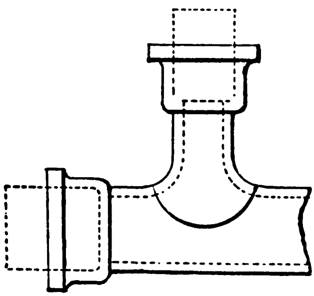


Fig. 133.

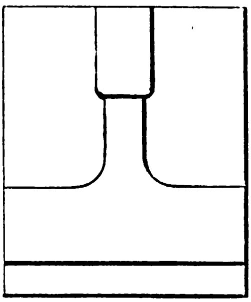


Fig. 134.

core-boxes are made for various sized pipes, and kept in the pattern stores ready for use.

CHAPTER XVII.

MISCELLANEOUS PIPE-WORK.

Turning Quick Bends in the Lathe.—Working Flat Bends.—Dovetailing Bends.—S-pipes.—Striking up in Loam.—Guide-line.—Guide-iron.—Strickles.—Sockets.—Pipes of Irregular Shape.

Common pattern bends of uniform section can be very conveniently turned in the lathe if we want two bends of the same size. Jointing four pieces together at angles of 90° and screwing them on the faceplate, we can turn the semicircular section with a templet in far less time than would be occupied

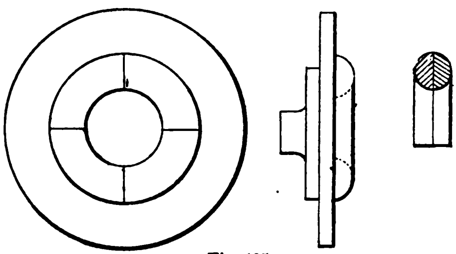


Fig. 135.

with gouge and chisel and spokeshave, and with more accurate results (Fig. 135). Removing the four half patterns from the faceplate, we dowel them two and two together, forming two bends.

If the pattern is of a flat curve, as in the common "eighth" and "quarter" bends of the pipe-makers (Fig. 136), or if it is a "reducing" bend, viz. a bend tapering from a larger to a smaller bore, the use of the lathe is out of the question. In these cases we joint truly together two pieces of wood large enough to take the outline of the bend, each piece being thick enough to take half the diameter of the bend. We dowel them together, and on the joint face of one mark the outline we require. Cutting to these lines we obtain the longitudinal form, and working with gouge, chisel, and spokeshave, guided by a semicircular templet, we get the transverse section. We mark the outline of the second half from the one just worked,

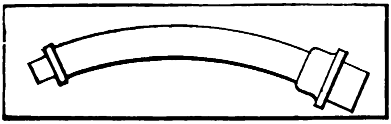


Fig. 136.

and cut that in turn with the half templet. Socket, bead, and prints are put on afterwards.

Some workmen have a way of cutting a bend, which, though slow, is safe, because there is no risk of undercutting, as there is sometimes where the roughing down is done recklessly before a templet can be tried on. It is to work the stuff, first of all rectangular in section (Fig. 137), gradually

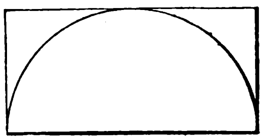


Fig. 137.

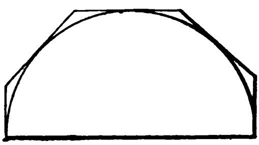


Fig. 138.

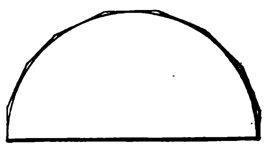


Fig. 139.

into a polygonal form until a nearly circular section is attained (Figs. 138, 139). The last remaining angularities being taken off with a spokeshave, a practically true circle is the result, which will not show wavy lines in the longitudinal direction. This is certainly the better method to adopt with a *reducing* bend, in which the diameter is constantly varying.

When the pattern is to form the elbow of a bend pipe (Fig. 140), it is necessary to attach the straight pieces of pipe each to their proper end of the curved portion. This we shall effect by means of a double dovetail, which is to be let into each of the portions of pipe which abut against one another (Fig. 141).

Sometimes pipes are made of very awkward shapes, to curve round parts of machinery, buildings, other pipes, &c.

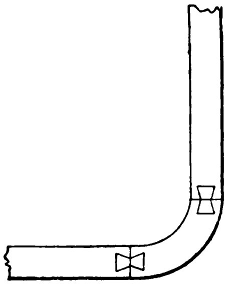


Fig. 140.

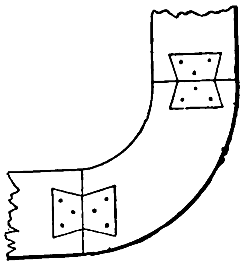


Fig. 141.

There may be two or three different bendings of the pipe not all in the same plane, and the flanges may have their faces at angles other than right-angles relatively to the axes of the pipe. The pipe-makers supply bends and S-pipes of various shapes, by which the desired shape can often be pieced up; but where space is limited, or where a graceful outline is wanted, we make a pattern; and this opens up the question of loam work. In these and many other cases we want but one casting, and if the pipe is of large or even of but moderate dimensions, the pattern would cost a great deal more than the casting itself. Then the question of wood *versus* loam becomes one for our consideration. In large castings the answer must be in favour of loam in almost every case, and in small castings also it will usually be cheaper to strike up the pattern in loam. But in those awkward-shaped pipes, such as Fig. 142, where the bends are not in the same plane, it costs less to knock out a rough unjointed pattern in wood than to strike it up in the foundry. Yet even in a case like this, if the casting were large, say over 6 inches in diameter, loam would be the cheaper.

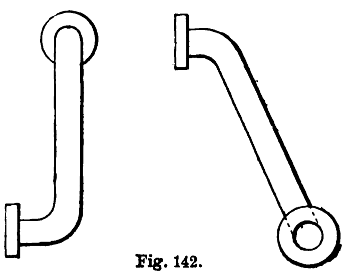


Fig. 142.

There are a number of "wrinkles" in the striking up of pipes in their various forms, so that a lad who had served his apprenticeship in a shop where no pipe-work was done would be "all at sea" on getting a start in a jobbing shop where pipes formed a part of the trade. So, taking the process up at the beginning, I will try to make the matter so clear that a pattern-maker who had never seen a plain loam pipe made should be able to prepare his work correctly. In pattern-making it frequently happens that, though the parts which the workman has to prepare for the moulder's use are few and simple in form, they involve more technical knowledge than work of more pretentious appearance. This is especially

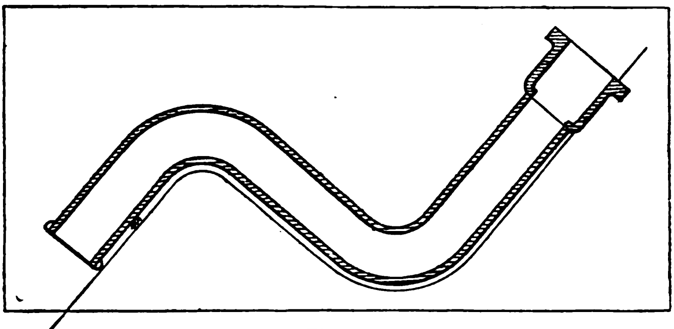


Fig. 143.

the case in loam work. The parts which the loam moulder requires are few and simple, and, like many other things, they are easily made—when one knows the way.

Let us commence upon the drawing. Fig. 143 represents the board, upon which we have drawn a 6-inch S-pipe in longitudinal section. Observe that there is a line drawn parallel with one side of the pipe, and at a distance of ¾ inch away from its edge. This is the "guide-line." We mention ¾ inch, not because that dimension is of any importance—it might just as well have been ½ inch or 1¼ inch—but the better to illustrate our explanation. By this line the foundry-smith bends a piece of ½-inch or ¾-inch square rod, which becomes, as we shall see immediately, the "guide-iron" (Fig. 144) for the "strickles." The strickles are the templets used for striking the transverse sections of the pipe in loam, and they have their edges cut in such a way that each strickle is maintained at its own proper distance from the guide-iron during the process of striking. Thus, the guide-iron being $\frac{3}{4}$ inch away from the body, the body strickle (Fig. 145) will be notched up $\frac{3}{4}$-inch from one edge of its 7-inch semicircle.

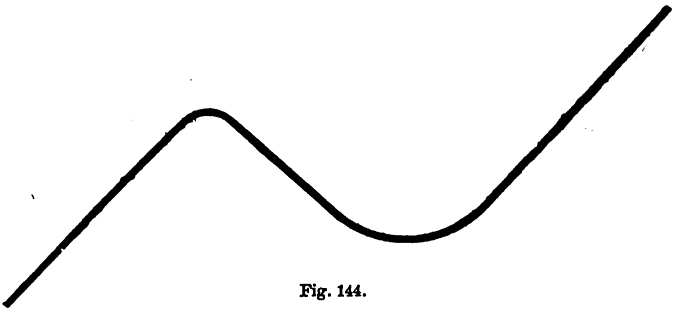


Fig. 144.

But the metal in the pipe being $\frac{1}{2}$ inch thick, the core strickle (Fig. 146) will be $\frac{3}{4}$ inch + $\frac{1}{2}$ inch = $1\frac{1}{4}$ inch wide at the shoulder. The edge of the strickle is chamfered like that of a loam board (Fig. 147). These strickles are used thus:—The

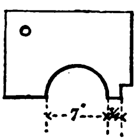


Fig. 145.

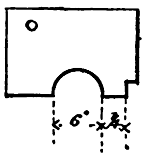
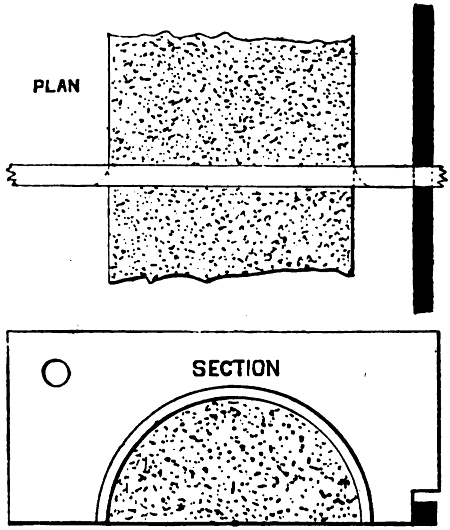


Fig. 146.

Fig. 147.

guide-iron is laid upon a plate on the foundry carriage, and kept in position by sundry weights resting against it. Then the "check," as it is called, of the core strickle (Fig. 146) is set against the guide-iron, and a semicircular body of loam is struck up (Figs. 148), following, of course, the contour of the guide-iron. The iron is then turned over and fixed again in a new position, and a similar half-core struck up, but the reverse hand to the first. These are run into the stove and dried. When dry, the *pattern* strickle is set against the guide-iron, and a thickness of loam struck over each half-core in turn. This also is dried; then both halves are detached from the plate, turned over joint to joint, and the rough pattern is complete (Fig. 149). A little touching up of the joints and a coat of tar will make it fit for the mould. After having been moulded, the thickness of loam representing the $\frac{1}{2}$ inch metal will be stripped off, and the core placed in the mould for casting.

If a flange is required for a loam-pipe, the hole in the flange will be of the same size as the core, and the body thick-



Figs. 148.

ness of loam will be shouldered back to afford steadiness to it. Obviously, a socket end would not be formed with strickles very readily, on account of the dressing off necessary where one diameter blends with another. Hence sockets are in most cases struck separately in the same way that a straight piece of pipe would be, but on a body of loam equal in diameter to that of the pipe for which they are intended, to be afterwards sawn longitudinally down the centre and slid or threaded over the pipe body. They are held in place during moulding with nails. The socket-core is either treated in the same manner or abutted against the body core.

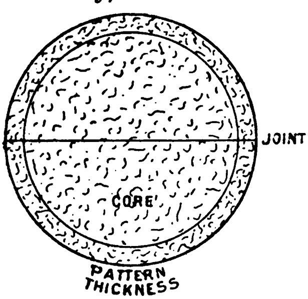


Fig. 149.

If we require pipes or hollow castings whose shape is not symmetrical, and which cannot, therefore, be struck on a revolving bar, or continuously by means of strickles, the difficulty is first how to get the core of the proper shape, and then how to insure an equal thickness of metal throughout. Take, for illustration, a reducing pipe connecting a rectangular valve-box or pipe with one circular in section (Fig. 150). Except at the ends the section is never uniform, so, except at the ends, a strickle or strickles cannot be used. In such cases the core body is first roughed up with a square strickle at one end and a round one at the other, and dried, then *rubbed* to its

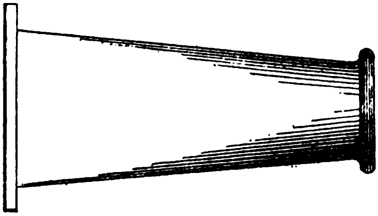


Fig. 150.

required shape with rasps and glasspaper. A number of strips are then prepared of the same thickness as the metal in the pipe. These are laid flat on the core in various positions, and their interstices are filled up with loam, which is strickled off level with their thicknesses. When the loam has set a little, but not baked, the strips are taken away, their vacant places filled up with more loam, and dried. When moulded, the thickness is stripped off as before, and the core placed in the mould. By this method castings of almost any size and shape can be made with uniform thicknesses of metal, and with much less trouble to the pattern-maker than would be involved in making a core-box with templets.

CHAPTER XVIII.

FLUTED AND ORNAMENTAL COLUMNS.

Apparent Difficulty of Moulding.—Number of Joints.—Central Foundation or Base.—Mouldings.—Flanges.—Working the Flutes.—Loam-board.—Square Core.—How attached.—Lines of Jointure.—Danger of Undercutting.

THESE, at first sight, would appear to present insuperable difficulties in the way of moulding. Looking at an architect's drawing, which somehow always does look more elaborate and enigmatical than the actual thing it represents, we wonder how such a complicated mass of ornamental work is to be got out of the mould. The pattern can be made like the drawing, but how to reproduce it in the casting is the difficulty. The use of drawbacks would perhaps appear feasible at first; but a little consideration usually reveals practical difficulties in the way of their adoption, and in most cases we are reduced to the method of loose pieces, as being, on the whole, the least troublesome.

We take, then, a fluted column like that shown in Fig. 151. Here we have a square base with mouldings, above that a fluted portion, then moulding again; after that a long fluted shaft, surmounted by an ornamental capital. It will be observed that the column in this case varies very much in diameter, being nearly twice as large in the lower portion as in the upper. We must strike out the column to full size, first in longitudinal outline, indicating the thickness of metal by dotted lines, and then in cross sections, at A A, B B, C C, to show the flutes. To make the pattern, we want a steady foundation—not the actual pattern, but that on which the pattern is to be built. Upon this base the fluted portion will be laid in strips, which strips will be drawn in succession from the sand, after the base is lifted out. A glance at the section (Fig. 152), will make my meaning clear. Divide the

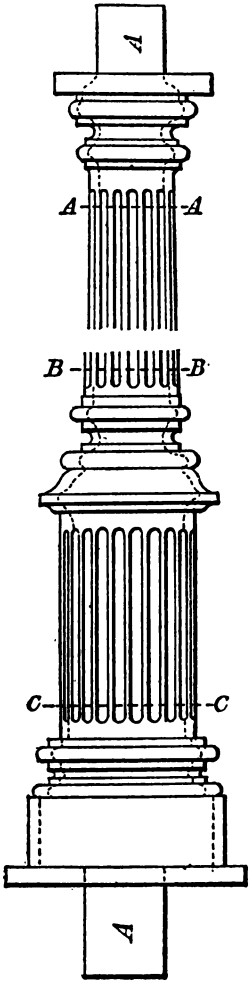


Fig. 151.

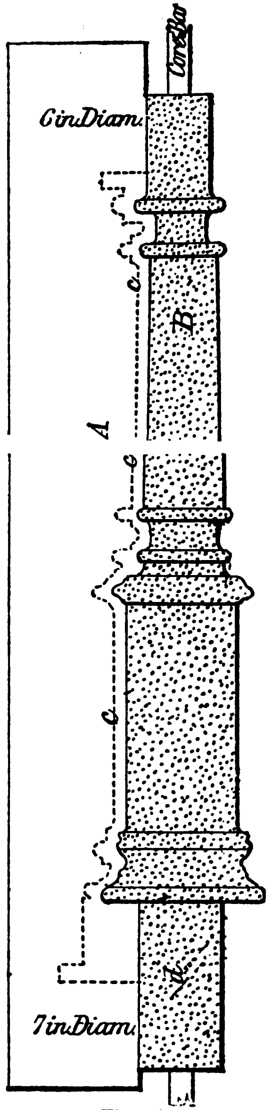


Fig. 156.

circle into such a number of parts that the flutes will draw readily from the sand; thus, a strip so wide as that shown in

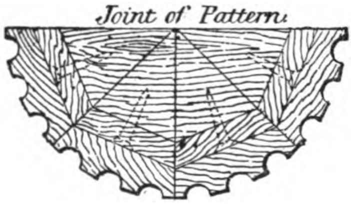


Fig. 152.

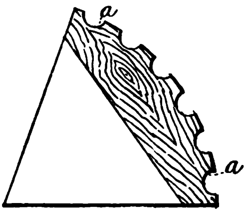


Fig. 153.

Fig. 153 could not possibly be drawn away without tearing down the sand at *a*, *a*. Let the edges, therefore, of the extreme flutings be plenty free enough, and do not, for the sake of lessening the number of joints, make the pieces so wide that opposite fluted edges will be *undercut* in relation to each other. There will not be less than six in any circle: eight are better, and in some cases twelve are desirable. We will have eight in this column. Divide the circle accordingly, and mark out an octagonal-shaped figure on each section to indicate the flat backs of the loose fluted pieces, allowing sufficient stuff at the bottom of the flutes for strength—say ⅜ inch or ½ inch. The central portion—that included between these lines—will be the base or foundation of the pattern. This may be solid if the column is not large, and if thoroughly dry stuff is available. But it is not advisable, in the case of a large pattern, to run the risk of its warping for the sake of saving the extra labour involved in jointing up; so we lag our central part up, just as in the case of a pipe pattern (Chapter XVI., p. 105). This will contain the same number of lagging pieces as there are to be loose strips. At the lower portion of the long flutes (Fig. 151, B, B), the diameter is larger than at the top, so that unless we taper the body to an equal amount, the fluting stuff will be thicker at the lower end than at the upper. It is of no consequence which course we adopt. The lower series of flutes, however, are twice as large in diameter as the uppermost ones, and the loose pieces would be inconveniently thick and heavy to handle in the mould, if made of that extra thickness. Instead, therefore, of giving the extra thickness to these, prepare pieces of the same length, and of such a thickness as will reduce these flutes to the same substance as the upper ones, and screw them on the main body (Fig. 154).

This part, which forms the foundation for the column proper, should have good close joints, to insure the requisite rigidity; it should be as straight as possible, and each flat should be altogether free from winding or twist. Mark out lengths of flutes, positions of mouldings, and faces of flanges in the joint, and begin to build up.

Turn the mouldings first, jointing them, of course, in halves, with the grain running transversely to the axis of the column. Cut them out to fit over the angular body, or else groove out the body in the lathe just where the mouldings fit, and bore out the latter to fit in these grooves. Screw the mouldings on from the *inside* of the column, since it is desirable that they should be left loosely attached to the body, to be withdrawn separately from the mould. Top and bottom flanges and square base will be prepared and fitted over similarly. Frequently small flanges are jointed diagonally, but in those of large size an inconveniently large moulding-box is rendered necessary; hence it is desirable to joint these latter parallel with their edges, and to put a little taper in their sides.

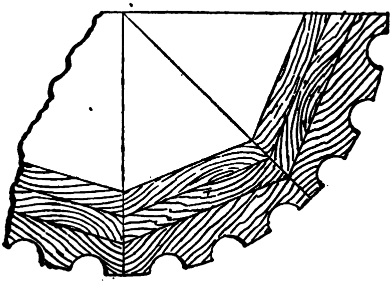


Fig. 154.

Then follow the flutes. As many flats as there are in the foundation body, so many separate joints will there be in the fluted portion. Each end of each flute will terminate in a hollow (Fig. 155). In preparing the stuff, square the pieces off just to the commencement of the hollows (Fig. 155, A, A). Screw on each end the narrow pieces, B, B, necessary to complete the length up to the mouldings. Then build up the strips in the usual way; instead, however, of gluing, screw (like the moulding) from the inside of the pattern. Afterwards work to a circular shape either in the lathe or with planes if no lathe long enough to take the pattern is available. Then the flutes will

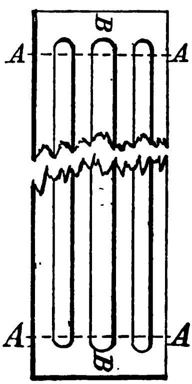


Fig. 155.

be divided round with compasses, and lined out with straight-edge—the end make-up pieces, B, B, unscrewed, and the flutes worked along with a round-plane, after which the end pieces will be replaced, and their hollows worked with a firmer gouge and glasspapered.

The end prints, A, A (Fig. 151), are turned out of the stuff with which the column is built up, or else made separately and screwed on, dependent on circumstances. Sometimes, also, where columns are made in quantity, a certain portion of the length of the print, or an independent collar concentric with the print, is made to fit into a bored hole in the end of the moulding-box while the pattern is being rammed up, and the core-bar has a collar also corresponding identically in size, by which a concentric position of the core relative to the mould is guaranteed. This, of course, applies to each end.

A round column with a square base such as ours is has a square core in that base, for which a special core-box is made, the round core being struck on a revolving bar. Fig. 156 shows the loam board which is used for striking the main core. A is the board, B represents the core, the dotted line, *c*, *c*, *c*, indicates the edge of the column, marked on the board to give the moulder his thicknesses of metal for the purpose of checking their accuracy when in the mould. It is usual to stamp diameters also at the ends as shown. Fig. 157 shows the box, in the centre of which a round print, *a*, passing through its entire thickness,

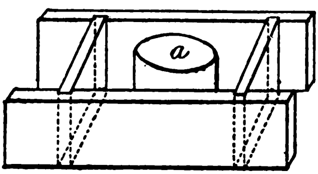


Fig. 157.

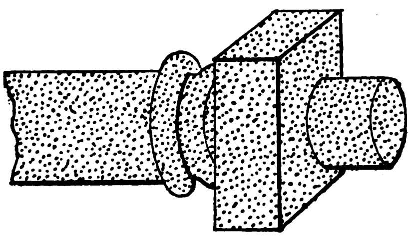


Fig. 158.

forms the hole, into which the shouldered portion of the long core (Fig. 156, *d*) is thrust (Fig. 158).

The foregoing remarks will enable the reader to understand the general process of column construction; but there is, as may be supposed, much variation of detail in columns of different designs. Still, the principle remains good in every case, so far as I know, that columns are not made by cores or drawbacks, but by *loose pieces;* and the one essential to be borne in mind by the pattern-maker is, that all parts shall withdraw easily from the mould. In highly ornate columns the pattern-maker is not required to do the carved work; but he has to joint the stuff in reference to the design, so that there shall be no difficulty in moulding after it leaves the carver's hands.

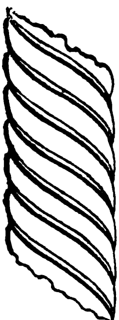


Fig. 159.

But it does not follow that a handsome column is difficult to make. A twisted design for a shaft (Fig. 159) does not involve any jointing at all, except the usual one in halves. Neither would an octagonal column like Fig. 160, excepting at *a*, *a* (section), where the undercut portion would be formed by two loose strips. Nor is it always desirable to joint radially from the centre, as in Fig. 152. In that case, if the flutes had been deep, we should have jointed like Fig. 161, else the sides of the flutes would tear the sand away at *a*, *a*. When the central fixing reaching from *b* to *b* is lifted out, the side flutes, A, A, are drawn out parallel with the joints, *c*, *c*, after which the other two will follow easily enough.

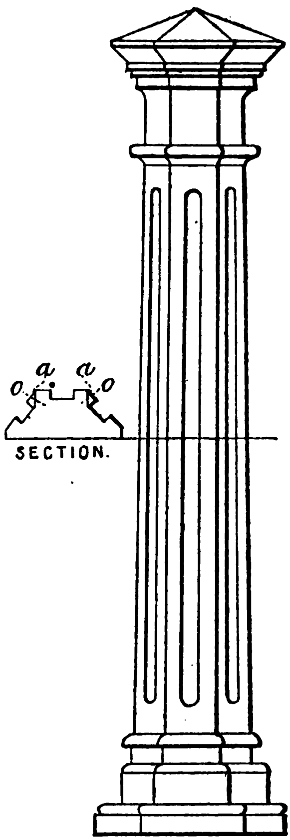


Fig. 160.

Another mode of jointing some kinds of ornamental work is shown at Fig. 162 (plan). Note that the central piece of the

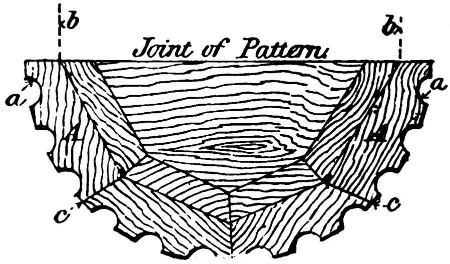


Fig. 161.

pattern is somewhat wider at A, where the joint of the mould

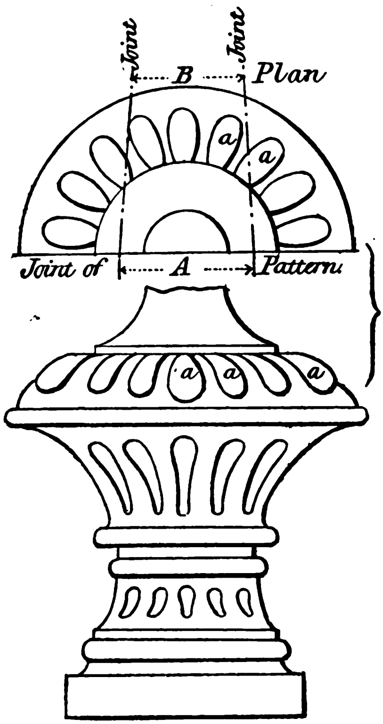


Fig. 162.

Fig. 163.

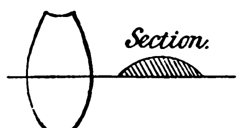


Fig. 164.

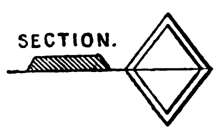


Fig. 165.

comes, than it is at B. This is for freedom of withdrawal from the mould, that piece being taken out first, the side pieces being removed afterwards. This joint is in frequent use, is easy to make, and allows of the side pieces being drawn away at any angle, even parallel with the joint of the mould—an arrangement possessing great advantages over the former in columns highly ornamented, such as those of Corinthian type.

In all columns and ornamental work generally this must be remembered, that no parts, however apparently insignificant, shall be *undercut*. It is more difficult to mend up work of this kind in the mould than any other; therefore, every little recess, flute, boss, swell, leaf, scroll, and moulding must have its edge so cut relatively to the direction in which it is to quit the mould that it shall cease to drag against the sand immediately that it is started by rapping. In doing this, it is sometimes, though not often, necessary to sacrifice a little of elegant appearance to the inexorable conditions of necessity. The undercut edges of the carver's work have thus to be tapered towards the outside of the pattern. But a little of this fudging will often save extra jointing, and the fewer joints there are in patterns of this kind the better: an experienced eye can always detect them in the castings. Looking at the swells, *a*, *a*, *a*, in Fig. 162, and the diamonds *a*, *a*, *a*, in Fig. 163, it would appear that they ought to be loosely wired on, and drawn out one at a time. But this would entail too much work. By fudging the carver's work, and tapering the edges (Figs. 164, 165), the main pattern joints make sufficient provision for the delivery of these. Even in working plain mouldings there should be *no absolutely square edges*, but a slight amount of taper should be given to every part.

CHAPTER XIX.

ESTIMATING WEIGHTS OF CASTINGS FROM THEIR PATTERNS.

Reducing to Feet and Inches.—Multipliers.—Sources of Error.—Specific Gravities.—Practical Example in Calculation.—Approximate Formula.—Bevel-wheels.—Mortise-wheels.—Pipes and Columns.—Decimals.—Useful Notes.

THE pattern-maker is often required to estimate the weight of a casting with more or less of accuracy, that accuracy being demanded either on account of the value of the metal, or by reason of the purpose for which the casting is intended. Accuracy within a hundredweight or two may be sufficient in some large castings, while in other cases, and in smaller castings, we may wish to be correct within a pound or two. Let us go a little into detail in this matter.

To calculate the weight of a casting, it is necessary to ascertain the number of cubic feet, or cubic inches, it contains, and to convert that number into weight by a multiplier. These multipliers vary, of course, with the nature of the metal to be employed. Thus, we know that a cubic foot of cast iron weighs on an average 450 lbs., and a cubic inch ·263 lb. These, then, are the multipliers by which cubic feet and cubic inches respectively of that metal are converted into pounds. Another multiplier easily remembered and commonly used is the number of pounds contained in a square foot of iron 1 inch thick. Such a plate weighs 38 lbs. Gunmetal, again, would require another multiplier; a cubic inch would weigh ·3 lb. Lead, steel, copper, and every other metal would appropriate its own multiplier. Hence the general rule is:—Ascertain first the number of cubic inches (or feet) contained in the pattern; treat this total with its appropriate multiplier: the quotient is the number of pounds which the casting may be expected to contain.

I use the word "expected" designedly, for it often happens that a most careful calculation is rendered very wide of the mark through contingencies lying beyond the control of the pattern-maker. I have had a difficult gunmetal casting, weighing 284 lbs., vary only 8 lbs. from the estimated weight, and an iron casting of 5 tons within 2 cwt.; and I have also, on the other hand, been a couple of hundredweights wide of the mark in castings ranging between one and two tons. There are many causes at work to produce such discrepancies. There is the custom of "rapping," which will make an appreciable difference in small work. There are different densities of metal, which will cause variations in the weight of large castings. A mould rammed unequally—that is, harder and softer in different parts—will allow a casting to swell, and to come out larger in the imperfectly made parts than the pattern. A large plate will increase in thickness, and therefore in weight. A broken mould will not always be mended up just like the pattern. These and many other things go to destroy the accuracy of a calculation; but we have to take things as they are, and frequently, judging by past experiences, we can make slight allowances for these and other contingencies, and thus produce, on the whole, very reliable results.

I spoke of the necessity for reducing to feet or inches, but there are other methods in favour with workmen. One of these is the method of specific gravities. The pattern is steadily immersed in water in a tank, the displaced water is allowed to overflow into a second vessel, and is then weighed. This, the weight of water displaced by the pattern, is multiplied by the sp. gr. of the metal in which it is to be cast, and the quotient equals the weight of the casting required. Thus, supposing a pattern displaced 4¼ lbs. of water, and that the sp. gr. of average cast iron be taken at 7·3, we shall get—

$$4{\cdot}25 \times 7{\cdot}3 = 31 \text{ lbs.} = \text{weight of casting.}$$

This is a very accurate way, presuming that a proper vessel is available by which no waste of overflow water occurs; but as it needs some special apparatus, it is hardly suitable for large patterns, and is seldom resorted to except in those cases where accurate weight is of the utmost importance.

Another and a most delusive method is to weigh the pattern itself, and multiply that by 16, which is supposed to represent the relative weights of dry yellow pine and cast iron. This leaves out of consideration the various densities of different qualities of pine, and the presence of screws, nails, or other foreign substances in the pattern. We simply mention this by the way, and pass on to illustrate the method we alluded to in the first place.

Let us take, as a practical example of the method of calculating by cubic inches, the cog-wheel in Fig. 8, p. 16, partly reproduced here (Fig. 166), for convenience of reference. This

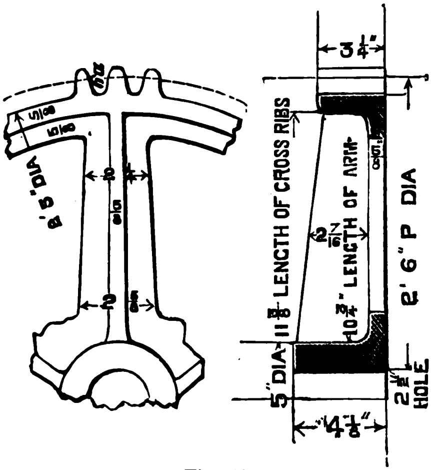


Fig. 166.

is a small casting, so we must reduce to inches, feet being too large a factor.

First of all then, take the rim. Its outer diameter is 2 feet 5 inches, its thickness ⅝ inch, the average or mean diameter, therefore, being 2 feet 4⅜ inches. To save the labour of calculation, we turn to a table of circumferences, and find that the circumference of such a ring is 89 inches; therefore, imagining the rim unrolled, it becomes—

$$1 \text{ strip } 89 \text{ in.} \times 3\tfrac{1}{4} \text{ in.} \times \tfrac{5}{8} \text{ in.} = 180{\cdot}6 \text{ cubic inches.}$$

Then the teeth. Imagine all the points of the teeth, *a*, broken off along the pitch-line and inserted between the roots, *b*. We see that a continuous ring is formed (neglecting the slight allowance for clearance). The mean diameter of this ring will then be taken, and its circumference deduced. At 2 feet 5⅝ inches average diameter, it is—

1 strip 92 in. $\times$ $3\frac{1}{4}$ $\times$ $\frac{7}{16}$ = 130 cubic inches.

The boss in like manner may be imagined to be a simple ring piercing the arms, and can be reckoned thus:

One solid cylinder 5 inches diameter $\times$ $4\frac{1}{8}$ long — one cylinder (the hole) $2\frac{1}{2}$ inches diameter $\times$ $4\frac{1}{8}$ long. A disc of 5 inches diameter by 1 inch thick will be found, on referring to a table of areas, to contain 19·6 cubic inches; one $2\frac{1}{2}$ inches diameter by 1 inch thick will contain 4·9 cubic inches. Subtract the one from the other, and multiply by $4\frac{1}{8}$; the quotient is the number of cubic inches in the boss.

$$19{\cdot}6 - 4{\cdot}9 \times 4\tfrac{1}{8} = 60{\cdot}2 \text{ cubic inches.}$$

The rib or flange within the rim will, at $\frac{5}{8}$ wide, average 2 feet $3\frac{1}{8}$ inches in diameter. Then it will contain—

$$85{\cdot}2 \times \tfrac{5}{8} \times \tfrac{5}{8} = 33{\cdot}3 \text{ cubic inches.}$$

There will be six arms extending from boss to rim, averaging $2\frac{7}{16}$ in width. Therefore we have—

Six pieces $10\frac{3}{4}$ $\times$ $2\frac{7}{16}$ $\times$ $\frac{5}{8}$ in. = 97·2 cubic inches.

Feathers or cross-ribs likewise—

Six pieces $11\frac{3}{8}$ $\times$ $2\frac{5}{8}$ $\times$ $\frac{5}{8}$ = 109·8 cubic inches.

Hollows add so little to the weight of a casting that they are generally taken no account of, or something else is set off against them. If the weight is desired so very precisely, they can be reduced to triangles, and the triangles in turn to rectangles.

These totals of cubic inches should now be added together, and multiplied by ·263, which will give the weight of the wheel in lbs.

Reckoning out, we find that there will be 161 lbs. weight of cast iron in this wheel.

There are rules given in various books for calculating the weights of wheel castings by their diameter and pitch. They are principally useful where approximate weights are desired, or where wheels are made by the same rules from which these formulæ are deduced. Three such rules given by three different authorities yield the following results in the wheel we have been considering. It contains—

75 teeth of 1¼-inch pitch, and is 3¼ inches wide, and 2 feet 6 inches diameter.

Formula from	D. K. Clark,	170 lbs.
,, ,,	Unwin,	171 lbs.
,, ,,	Box,	158·4 lbs.*

In a wheel weighing several cwts. the difference would be more marked. The ring of a bevel-wheel might appear at first sight to offer a difficulty in the way of calculation, its diameter varying at every point. But if we take average diameter and average thickness, it will be just the same as though we divided it into an infinite number of sections, and reckoning each separately added their totals together afterwards.

The recesses in a mortise-wheel will not complicate the matter in the least, for after finding the number of cubic inches in the ring, on the assumption that it is solid throughout, we need then only find the number of cubic inches in each mortise, multiply that by the number of mortises, and subtract the sum total from the number of inches in the solid ring.

A more intricate piece of work, such as a steam cylinder, with passage and perhaps jacket cores, with webs of metal of odd shapes, curved brackets and feet, and such like, should be divided out piecemeal on the drawing itself in order to get

* They are the following:—

$$W = (\cdot 05 + \cdot 08\,p)\,d\,(1 + 0\cdot 10\,d).$$

d = diameter in feet.
p = pitch in inches.
·05 = constant.
W = weight per inch of breadth.

Bevel wheels to be taken at ⅔ to ¾ the weight of spur ones.
—(D. K. Clark, "Rules, Tables, and Data," p. 741, edit. 1878.)

$$W = K\,N\,b\,p^2.$$

p = pitch.
b = breadth of face.
N = number of teeth.
K = 0·38 for spur wheels, 0·325 for bevels.
—(Unwin, "Machine Design," p. 302, sixth edition.)

$$W = (D \times P \times W) + (\sqrt{D \times P \times W}) \times M.$$

D = p diameter in feet.
P = pitch in inches.
W = width on face in inches.
M = 12 for spur wheels, 10 for bevels.
W = weight in lbs.
—(Box, "Mill Gearing," p. 24.)

exact dimensions. Without this precaution we are likely to reckon some portions twice over, or to omit some parts altogether. In reckoning, it should be our aim to simplify matters as far as possible by reducing everything to *circular* or *rectangular* form.

The weight of parallel pipes and columns may be obtained from tables, either by tables of weights for pipes of various thicknesses, or by a table of solid cylinders. Thus—tables are given in all engineers' books of reference of the weight of solid cylinders a foot long.* All we have to do, then, is to take the weight of a cylinder equivalent to the *outer* diameter of our pipe, and subtract from that the weight of one equal in diameter to the *bore* of the pipe. Or if such tables are not at hand we can get the *average* diameter, thence obtain the circumference, and multiply that by the *length* of the pipe and its *thickness*. In a taper column we must take the *average* diameter, and reckon then as though it were parallel.†

If we have a column with a quantity of mouldings and ornamental work, where it would be impossible to strike an average, we must divide into *sectional lengths*, calculate each separately, and adding their totals together, thence deduce the weight.

If a casting weighs several cwts., it is inconvenient to have a sum total in lbs. The multiplier ·009 will convert lbs. into cwts.

In the calculation of weights I find decimals more convenient than vulgar fractions, and inches more convenient than feet. Thus it is easier to multiply—

$$11{\cdot}87 \text{ inches} \times 6{\cdot}75 \text{ inches} \times 4{\cdot}62 \text{ inches}$$

than to multiply

$$11\tfrac{7}{8} \text{ inches} \times 6\tfrac{3}{4} \text{ inches} \times 4\tfrac{5}{8} \text{ inches},$$

and to multiply

$$69{\cdot}75 \text{ inches} \times 14{\cdot}37 \text{ inches}$$

than

$$5 \text{ feet } 9\tfrac{3}{4} \text{ inches} \times 1 \text{ foot } 2\tfrac{3}{8} \text{ inches}.$$

* See Table in Appendix, p. 255.

† A correct rule for finding the weight of a lineal foot of pipe in lbs. is this:

$$W = K\,(D^2 - d^2).$$

W = weight of a lineal foot in lbs.
D = outside diameter of pipe in inches.
d = inside „ „ „
K = a multiplier 2·45 for cast iron.
2·82 for brass.

We have assumed that tables of areas and circumferences are always ready to hand—as they are in the workshop. But when a man is sent out to take dimensions for a casting, it sometimes happens that an approximate weight is required at the same time. It is well, therefore, to bear in mind that—

$$\text{Diameter}^2 \times \cdot 7854 = \text{area}$$
$$\text{Diameter} \times 3\cdot 14159 = \text{circumference,}$$

Or,

$$7 : 22 :: \text{diameter} : \text{circumference,}$$

and that cubic inches divided by 4 = pounds, nearly.

Multipliers for the Common Metals.

Cubic inches ×	·263	=	lb. cast iron
,, ,, ,,	·288	=	,, steel
,, ,, ,,	·3	=	,, brass
,, ,, ,,	·41	=	,, lead
,, ,, ,,	·32	=	,, copper
,, ,, ,,	·266	=	,, tin.

See also Appendix for useful and more extended tables.

CHAPTER XX.

ON THE USE OF CORES AND DRAWBACKS.

Different Methods of Moulding.—Value of Experience.—Gasholder Bracket. — Drawbacks. — Grid.— Travelling Girders.— Cylinder.— Drawbacks.—Joints.—Lathe-bed.

THE pattern-maker is often in doubt as to the best method of taking out the recessed portions of a casting. Cores, drawbacks, dowelled and wired pieces, are the usual means resorted to for the purpose. Sometimes all three methods are practicable, sometimes only two; rare are the circumstances in which the workman is reduced to one plan without having the option of another. Broadly it may be said that castings can be made from patterns which are exactly like themselves. But in very many instances it would be very unpractical, unwise, and expensive to make them thus. Because a moulder can make drawbacks *ad infinitum*, and form joint over joint, as many as it is possible to put in the pattern, that is no reason why a vast amount of unnecessary labour should be undertaken which could have been avoided by a little judicious coring out.

Yet we need not fall, on the other hand, into the error of taking out everything with cores in order to lessen the difficulty of moulding. For cores are expensive, requiring making and drying, and the core-boxes for a piece of work will very often entail more labour in the pattern-shop than the pattern itself. Looking at the drawing of an intricate piece of work for the first time, it is not easy to arrange everything in detail, and to foresee every contingency that may arise, before deciding how best to make the pattern. Yet there is a rough-and-ready kind of intuition acquired by experience, and it is marvellous how readily a skilled hand will unravel the difficulties of a fresh job, and decide in his mind how he will set about it. Taking the various methods in succession—loose pieces, cores, drawbacks—he soon perceives which is feasible and which is impracticable; then what is easy and what is not so easy; then, lastly, which is good and which is best of all. So that before the man with less experience has grasped the leading features of the drawing, the other has

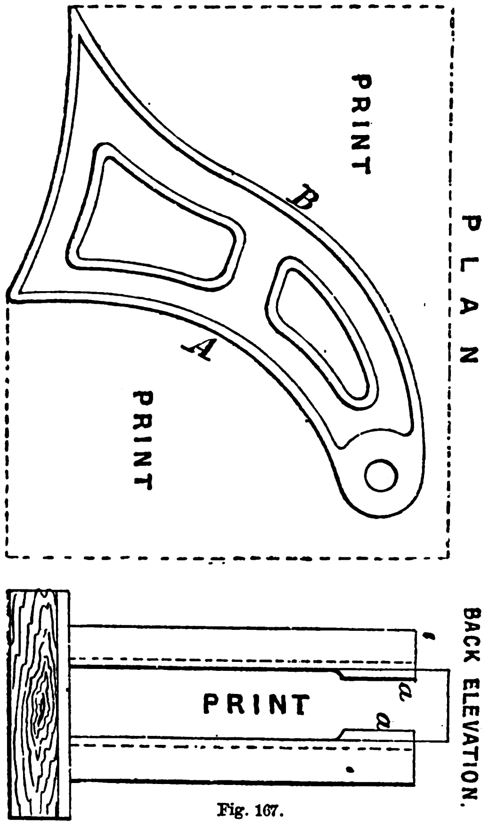


Fig. 167.

already settled in his own mind the lines upon which he intends to work.

But this almost unerring kind of intuition only comes after many years' habitual observation; and also, let us add, after many dearly purchased errors, for here, as elsewhere, failure is the stepping-stone to success. To apprentices and young hands there is nothing which presents such difficulty as this of the best method of moulding; and, in point of fact, it is seldom left to their choice. When the foreman gives out a job he will almost invariably, except in very simple work, give directions as to the way in which it is to mould, and even then a watchful supervision is necessary with the less experienced hands. It is to help such as these in the matter of moulding that this chapter is written. The simplest way, perhaps, will be to illustrate our meaning as we go along by examples taken from actual castings.

Take, for instance, a double bracket (Fig. 167), such as is used for carrying the guide-wheels of a gasholder. Here is a casting whose pattern might be made to mould with the edge

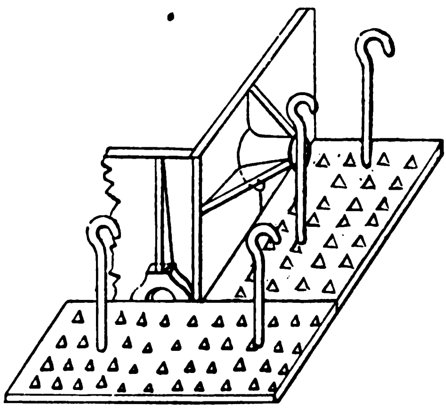


Fig. 168.

A in the bottom and the edge B in the top. Certainly the fillets or flanges round the edges would not allow of the pattern being drawn, but the sand forming the entire sides, including their bounding edges, could be drawn away on plates or "drawbacks."

In case some of my readers should marvel respecting the meaning of this curiously applied term, I will explain. Fig. 168 represents two drawback plates laid against a pattern. On one side of the pattern is a long boss with ribs, on the other a thick bearing with its bracket. We suppose, as often happens, that there is not sufficient central space to draw these projecting pieces into—that cores would mean more work than the job is worth, and that the sides are too deep to allow of jointing down from the top. Then we ram the sand around these particular sections of the pattern upon these plates, dividing the sand on each plate from that on the other

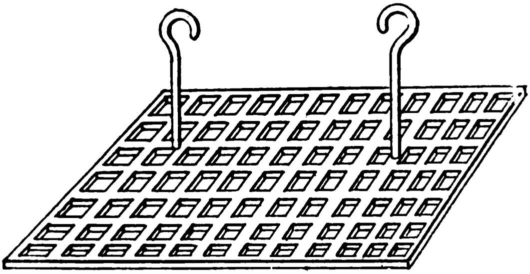


Fig. 169.

and from the outer sand by joints of brown paper or of parting sand, and afterwards "draw back" the plates, with their complement of sand, from the pattern. The pattern is then lifted out and the face of the mould cleaned and blacked,

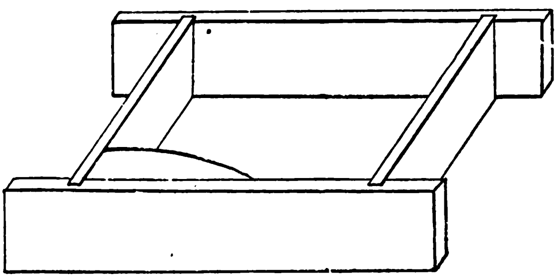


Fig. 170.

after which the plates are brought into position again by the paper or sand joints.

Well, we could make the pattern of the guide-roller bracket to mould thus, but we should not care to adopt this method in this case. For the drawbacks would be large and heavy, and the flanges and inner edges of the pattern being square would tear away the mould, there being a vast difference between lifting a pattern out of the mould by gently tapping, and tearing the sand forcibly from the pattern. We should find drawbacks expensive in this case.

But it might be made to mould flat side down, just as represented in Fig. 167, plan, in which case the middle space (Fig. 167), back elevation, would have to be taken away on a "grid," of which Fig. 169 gives a sketch. One side of the pattern would then be left loosely dowelled to come away in the top box, and temporary distance blocks would maintain the sides at their proper width apart during ramming. Yet neither would this be a wiser course to adopt in a pattern of so flimsy construction, though it would be well suited to a stronger piece of work. In this case no two castings would come out alike, but the sides would be winding and not parallel with each other. We should, therefore, taking these things into consideration, unhesitatingly vote for a central core (the outline of which is indicated by the dotted line). Then our double bracket would mould on its side, as in Fig. 167, plan; the core-box being plain (Fig. 170), would involve little labour, and the distance between the frames (maintained parallel by the core-print) would be perfectly uniform. The facing bosses,

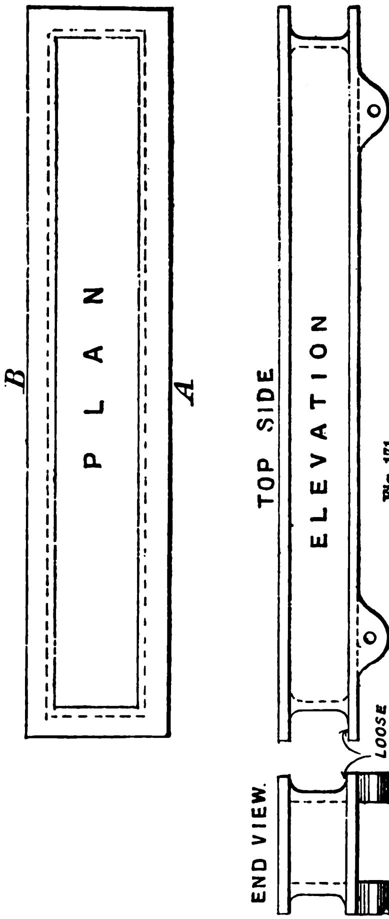


Fig. 171.

a, *a*, will either be put, one on a bottom board, the other on a crossbar dowelled on the top edge, or be measured into place while the core is being made. Of course the top pattern frame would be dowelled upon the print.

Take next a type of cast-iron girder used at the ends of the gantries in overhead travelling cranes (Fig. 171), and which carries the flanged running wheels. Should we take out the centre in this case with a core? The frame in this instance also is double, with a central space, and here analogy would lead one at first sight to think it advisable to mould it upon its side, making A the bottom and B the top, and to take out the central space with a core. But no; here we should use neither cores nor draw-backs, for although we cannot leave the bottom flanges loose round the edges, for the simple reason that owing to their width they could not be drawn inwards, we can leave the entire flange, made as a frame, loosely dowelled to the bottom edges, to be parted from the rest of the pattern by a sand joint. So our pattern will be exactly like the casting in this case, and the trouble of making a plain sand joint will be far less than that of making prints and a core-box, and preparing the cores besides. Fig. 172 shows the pattern in sand completely rammed up.

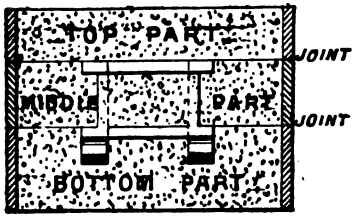


Fig. 172.

Take another form of travelling girder (Fig. 173), where,

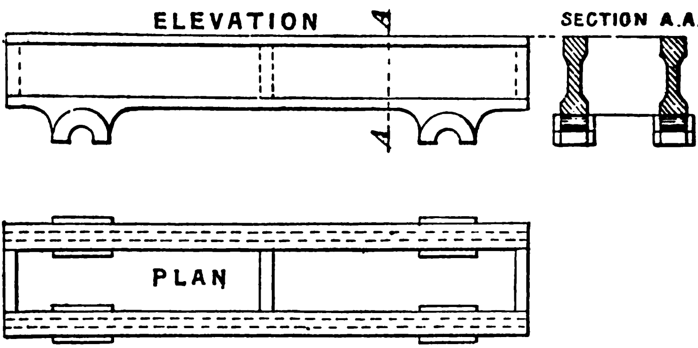


Fig. 173.

instead of broad flanges, we have thin fillets, and bearings whose faces stand out beyond the fillets. Here we should leave bottom fillets and bearings loosely wired on, both inside and outside. Our sides are, say, 1½ inch thick, and our fillets 1 inch. These latter would draw into the space left by the pattern after its withdrawal; but if, as we will suppose, the bearing-blocks stand out an inch beyond these, they clearly will not come up through 1½ inch space. But we can get over the difficulty of increased thickness in one of two ways here. We could put the blocks on, 1 inch thick, outside the fillets, not screwed, but wired, and draw them *after* the fillets; or we can take away the middle sand on plates, after the sides of the pattern are withdrawn. In a shallow pattern the former entails least trouble; but in the case of a deep girder the latter is the one to be chosen, since it has this great advantage—that both the outer and inner mould is more readily accessible for mending up, blacking, and so forth, when the middle sand is removed than when it remains *in situ*. Fig. 174 shows the pattern rammed up.

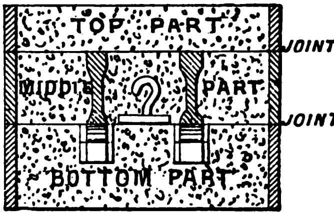


Fig. 174.

The cylinder (Fig. 175) as used in vertical steam cranes affords an illustration of drawbacks, loose pieces, and cores in one pattern. Observe the shape of the feet, A, A; clearly it will not mould on either side, because the cranking of the feet will not allow them to be drawn into the pattern space, and the sand overlying them will prevent their coming up with the pattern, no matter whether we joint it through the plane of the passages, B, B, or parallel with the steam-chest face, C, C. An accurate core, moreover, would be a troublesome thing to make, for it would have to include the entire foot with its bracketings, its bottom face of course excepted. But there is no difficulty if we use drawbacks, and they are very readily manipulated here, D, D. Fig. 175 shows the pattern completely rammed up in a three-parted box, with joints and drawback plates shown. The section is supposed to be on the face of the cylinder flange. Fig. 176 shows the middle and bottom parts of the mould when the cylinder body has been removed and the drawbacks are lifted out, but before the feet are drawn or the middle box parted from the bottom. The section is taken through the middle of the exhaust, the feet, and the steam-chest flange. The exhaust flange and that portion of the body above the foot are in the drawback (not shown), so that that portion of the mould shows a clear space right down to the flange. Fig. 177 shows the right-hand drawback lifted out. The left-hand one, of course, will be similar, except that it will contain also the exhaust portions just mentioned.

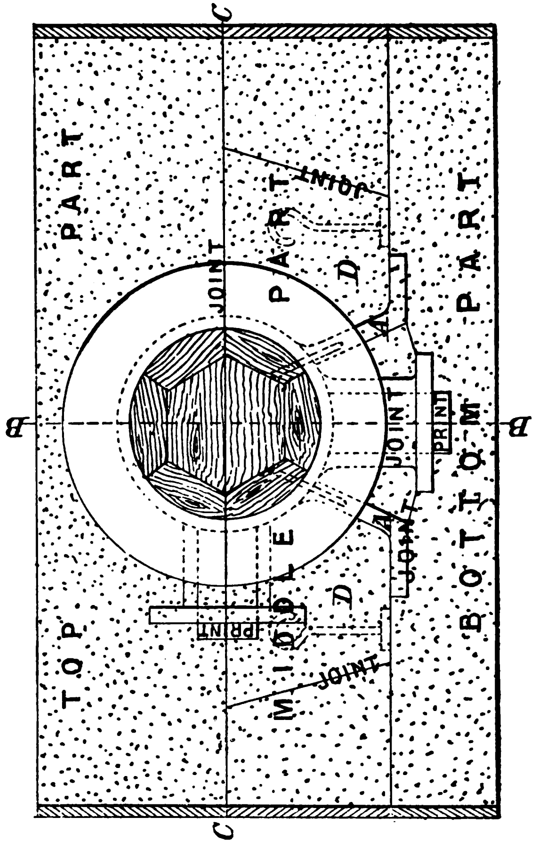


Fig. 175.

Then, further, we must either core out underneath the steam-chest flange or leave it loose. A core would be far too troublesome, so by leaving that flange loose we can joint underneath it, and draw the half-pattern from one box and the flange from the other. And the steam passages must be taken out by cores, the prints for which will be placed on the flange.

The more completely to illustrate this chapter on the diversified methods of moulding patterns, let us discuss the different methods in which a lathe-bed might be made. Every one

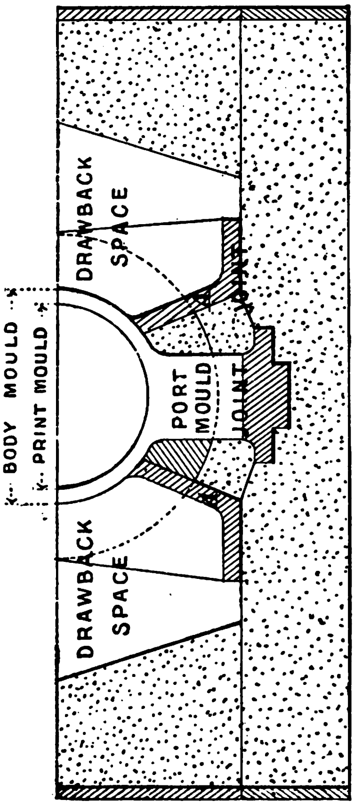


Fig. 176.

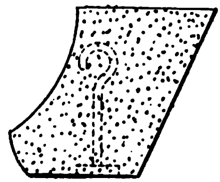


Fig. 177.

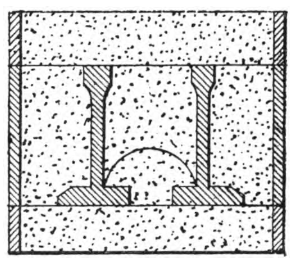


Fig. 178.

knows the familiar form of a lathe-bed, with V-shaped edges for the saddle of a slide-rest. The V-strips are planed all over, and that settles at once their position in the mould. They will be in the bottom, to secure the advantage of the soundest and cleanest metal.

But we require to settle something beside the fact that the strips are to be cast downwards before we commence the pattern, and that is, how to taper the sides. Looking at the imaginary mould in section, Fig. 178, we see clearly that, though the sides of the bed can be made to withdraw readily from the sand, it is impossible to lift out the inner and outer bottom strips through the spaces left by the sides. Hence our idea would be to remove some portion of this overlying sand, and so render the strips accessible. From this point of view the pattern could be constructed in three different ways, in order to provide for three methods of moulding and the ready removal of the strips in each case.

The three diagrammatic views, much exaggerated, will clearly illustrate these three methods. In the first instance (Fig. 179) we plane no taper in the stuff which forms the sides, but give, instead, $\frac{1}{4}$ inch to $\frac{1}{2}$ inch of taper (according to the depth of bed) to the ends of the bridges or crossbars, so that the bed shall spread bodily in section. Here the sand forming the inside of the bed will be lifted away on plates,

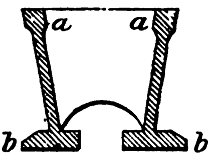


Fig. 179.

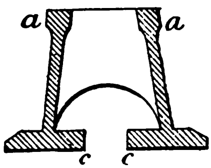


Fig. 180.

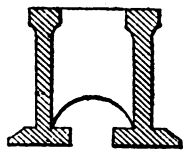


Fig. 181.

after the removal of the top box, and the pattern itself will be drawn immediately afterwards. The fillets, *a*, *a*, would have to be wired on to lift with the inner sand, and the outer Vee's, *b*, *b*, would also be left loose to be drawn into the middle space left by the lifting out of that sand.

The process adopted in method two (Fig. 180) would be the same in principle as the first, but the *modus operandi* would be exactly the reverse. Here the outer sand would be lifted away, either on drawbacks or on an outer encircling plate; then the pattern would be drawn, leaving the middle sand remaining. In this case the inner strips, *c*, *c*, and the outer fillets, *a a*, would be left loose. In the third method (Fig. 181) the medial lines of the sides are parallel, and taper is given to their inner and outer faces. The bottom strips, both inside and outside, are wired on, and the screws which unite the sides to the crossbars are withdrawn one by one as the ramming goes on, and when all is rammed up and the top lifted away the pattern is drawn piece by piece, leaving the sand behind. Then either middle or outside is taken away on plates, and the loose strips drawn in. Fig. 182 shows an encircling plate as used for lifting the outside of a mould away bodily.

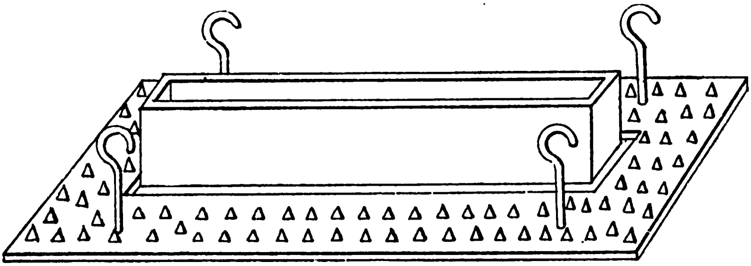


Fig. 182.

The last method is to take out the inside with cores (Fig. 183). It makes a cleaner and truer casting, and as the cores are very plain the expense is not great. Only the outer pieces, *a*, *a*, are wired on. The core-box may be made of the *entire* length of the pattern, and the bridges put in, as into the pattern, or short core-boxes may be made to reach from bridge to bridge.

Some of my readers may be disposed to put the question, Why lay so much stress on matters of moulding, instead of describing simply how such and such patterns are made? I reply, that in any save the simplest jobs, scarcely any two men would go to work in precisely the same way. A pattern-maker must understand moulding well, and even here the usages of shops differ. The bare description of one pattern would be of little assistance in the construction of another, having perhaps a general resemblance to that, yet differing from it (from the moulder's point of view) in some very important particular. I know of no trade where the methods of working differ so widely as in pattern-making. Many patterns can be made to mould in three or four different ways, and the workmen, therefore, instead of proceeding in certain set grooves, like those of many handicrafts which will occur to the mind, must devote to each new job some amount of originality of thought and modification of construction. It is for this reason that piecework is so difficult of adoption in the pattern shop.

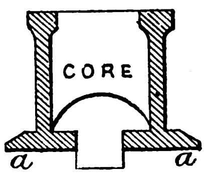


Fig. 183.

CHAPTER XXI.

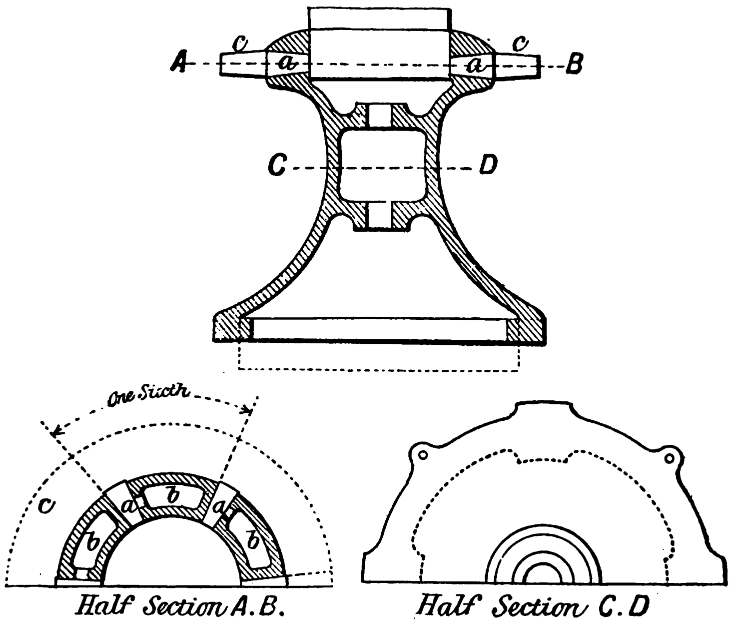
LOAM PATTERNS, &c.

Why used.—Methods of making.—Capstan.—Bar Cores.—Boards.—Core-box.—Remarks on Wooden Patterns.—Loose Pieces.—Stopping-off.—Pipes.—Wheels.—Brackets.—Skeleton Patterns.—Rings.—Levelling-block.—Crane-centre.—Tank-plate.

A LOAM pattern is quite a different thing from a loam mould. We made the boards for a loam mould in the case of the large cylinder (Chap. X., pp. 69, 70). We will now make the boards for a loam pattern, and that pattern shall be a common capstan. In cylindrical work a loam pattern is advisable when the mould is so small that a man could not conveniently work within it to strike the board round, and yet so large that a wood pattern becomes too expensive. This is usually, in fact, the ultimate consideration: the relative proportion the cost of the pattern bears to the value of the casting or castings. Thus, in the case of a capstan, if we had one or two castings only to make, we should use a loam pattern, but if we required a dozen or twenty castings all alike, we should consider a wood pattern the cheaper. Though its first cost would be considerable, the subsequent expense of the moulding would be diminished in a greater degree.

A loam pattern, then, is a pattern made in loam instead of in wood. Both are exactly alike in outline, the materials only of which they are constructed being different. A loam pattern, like a loam mould, is struck up, but the boards are cut the reverse to those intended for a loam mould. Brackets, however, facings, flanges, &c., not circular, are made as separate pieces, and attached to the loam body by means of nails. Where there is a longitudinal centre core, as in a pipe, a cylinder, or, say, in our capstan, it is customary to strike the core up first on the bar, to dry it, and give it a coat of blacking, and then to strike the body of the pattern over that (see Chap. XVII.). After the pattern is moulded the body thickness is stripped off, and the core is placed in the mould for casting. Evidently this can be adopted only where one casting is required, and if this happens to turn out a "waster," the labour of striking up a pattern has to be gone through again. Therefore the question of striking up a pattern on another bar distinct from the core is an economical matter to be decided by the character and circumstances of each individual job.

Reverting to our capstan body, then (Fig. 184). We take the body, because that alone is made from a loam pattern,



Figs. 184.

omitting the base and cap (not shown) as being wood patterns of so simple a character as to call for no comment. Observe that there are six cores, *a*, *a*, required at the upper part of the capstan for the insertion of the lever bars. There are also lightening spaces, *b*, *b*, between these recesses (Section A, B). We can put in these cores in one of two ways. We might have six prints arranged equidistantly round the pattern, and left loosely set, so that they might be drawn singly into the mould. But as it would be difficult to set them properly in loam, we consider it better to make a print continuous round the circumference, *c*, *c*, and to shape the cores in such a way that they will fill the print ring quite up, or "stop themselves off." Having thus decided, we simply make our boards as indicated in the sketches, Fig. 185 representing the board which strikes the core, Fig. 186 that which strikes the pattern. Stamp the

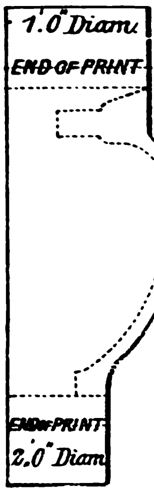


Fig. 185.

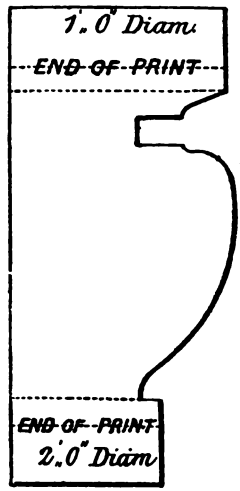


Fig. 186.

diameters as shown, and mark ends of prints. The dotted line in Fig. 185 shows thickness of metal. Two little battens on the same figures, *a*, *a*, hold the bosses which carry the central spindle. When the core is struck up, of course these projecting bosses form recessed grooves or rings, and if the board were drawn back with these firmly attached to it a portion of the loam would be torn away also. But these are unscrewed after the core is made, the main board is drawn back, and then they are taken away parallel with the axial line. Fig. 187 shows the same enlarged. When the loam pattern is struck and finished, supposing the thickness of metal is struck on the core, it will in section have the appearance shown in Fig. 188.

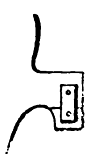


Fig. 187.

Then we take the core-box, and here we observe that a plain tapered box, similar in shape to the holes required for the capstan bars, would be of no use. The sides of the circular print (tapered) and the sides of the holes are not in one plane, but inclined towards one another, and we ought to put this double taper in the core.

It sometimes happens that in a tapered core we can give the same taper to a print which we give to the core, and then the sides of the box are straight bevelled; but in this case such a method would prevent the pattern from moulding. Hence we shall cut the top and bottom edges of the box to the same angle as that to which the sides of the print and the

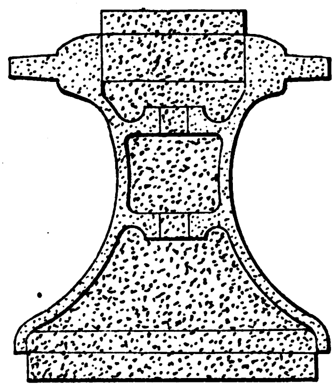


Fig. 188.

sides of the bar recesses are inclined towards one another (Fig. 189, elevation). This will, of course, necessitate the addition of a bottom board to the core-box, of the same shape as its edge. Further, the cores are intended to stop themselves off; therefore they must be so made that when all are put in place the ring print shall be completely filled up. This we shall accomplish by making the print portion of the core-box to fill up exactly a sixth of the ring print. Then, again, we have cores between the bar sockets, to lighten the casting and to insure regular contraction. The gas must be brought away from these cores; so to insure a communication with the outer air we will make the lightening cores unite with the bar cores by the round holes indicated in section, Fig. 184. Therefore one core-box will fill up print, take out bar and lightening cores in one, and all the air will be drawn away at once into the print.

We may note by the way that although we have selected this capstan as an illustration of a loam pattern, it is, where the quantity is sufficient to pay for it, made in wood—moulding in the same fashion, with prints at each end, and a central core struck up on a revolving bar against a board. When, however, capstans are made in large numbers, it is better to have the patterns to leave their own cores. The capstan then would mould upright exactly as it stands when in position, and its pattern would have two or more horizontal joints, depending on circumstances; one at the centre, where the diameter is

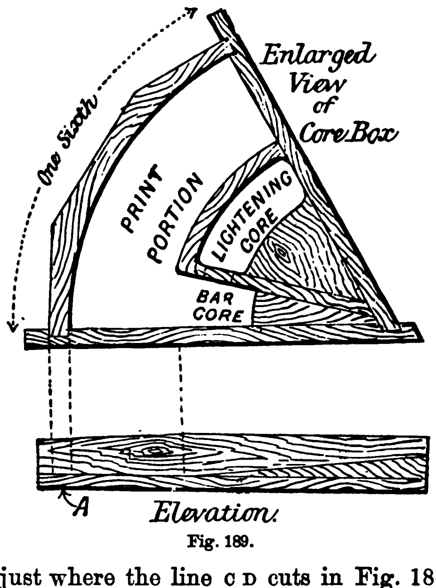


Fig. 189.

smallest—just where the line C D cuts in Fig. 184—and one at the top of the bar cores. The bar cores may be set in prints, or be made to rest upon small oval cores lying upon the central core. The various portions of the pattern will be built up in segments and turned to templet, good glued joints and pegging being essential. The loose joints, where the pattern parts, are either dowelled or turned with shoulders, to drop into one another. The tapering shape of the capstan affords every facility for this way of moulding.

While the subject of the various methods of moulding patterns is under discussion, a few remarks on loose pieces, stopping off, and skeleton patterns will also be in place.

Loose Pieces.—Take the annexed plate (Fig. 190). For some reason or another, generally for the purpose of securing a sound face, as in a surface plate, this must be cast face downwards. Then the proper way is to leave the deep ribs loosely dowelled on. We do so in order that they may be lifted up

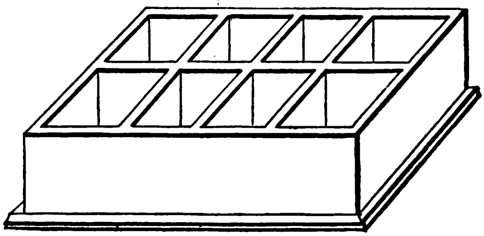


Fig. 190.

with the top sand, to be properly rapped and drawn out afterwards, rather than that the sand should be torn away from the ribs and entail a deal of mending up. If these ribs were shallow, the necessity for leaving them loose would not exist; but, in the case of deep top lifts, there should be no exception to this rule.

Somewhat akin to this is the case of a pipe or cylinder. We know the rule is almost invariably to make the patterns of these in halves, jointed longitudinally. The top half of the pattern is then lifted in the top box and rapped and drawn away from the sand. Occasionally, however, we see a pattern made solid, either through ignorance, or from a false idea of economy, and then the evil results of such a method are apparent in broken edges in the sand, and lapping joints in the casting, the result of imperfect mending up. The evil is seen at its maximum where a loam pattern is used. Here a joint is not practicable, and the rough loam tears the top mould so much that mending-up pieces are always necessary.

Further, if we take a common trolly-wheel, though the back boss is almost as often fastened on as left loose, it is better to leave it loose, with a stud in the centre. For, although, owing to the abundant taper given to such bosses, the top box will often be lifted away without causing fracture of the sand, yet a little unsteadiness in lifting will certainly break the mould, and then the boss must be unscrewed from the pattern and embedded in the broken mould for the purpose of mending it up. The advantage becomes still more obvious if there are deep arms (Fig. 191) in addition to the boss in the top, so that in bevel-wheels, deep spur-wheels with double-ribbed flat arms in the centre of the rim, and similar instances,

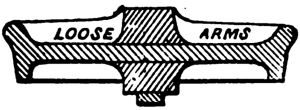


Fig. 191.

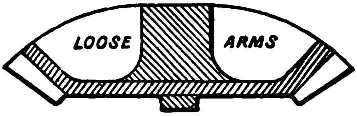


Fig. 192.

the portion in the top should be dowelled on—boss and arms usually being fastened together and lifted out as one (Fig. 192). There are few patterns, indeed, in which some parts have not to be left loose, either for convenience of being lifted with the top part, or of being drawn in at the sides, as mentioned in the last chapter.

Stopping Off.—We have used this term several times in the course of these chapters. It is one in common use in the workshop, and means broadly the modification of the shape of a mould, so that the casting shall be, to the extent of such modification, unlike the pattern from which it is made.

Much can be done in this way by the moulder, and considerable expense saved thereby. A comparatively small amount of labour will often save the cost of a new pattern, or that

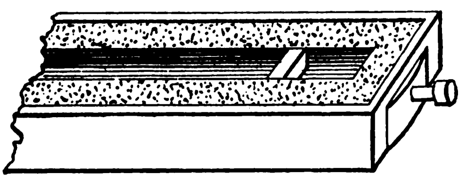


Fig. 193.

of extensive alterations to one already in stock. Take, for example, the simplest case we can instance. Say we have a solid plunger pattern, 12 feet long, 6 inches diameter, and we want a casting of the same diameter, but only 10 feet long. If we cut the pattern off, we spoil it for the greater length if required at any future time; but neither should we make a new 10-feet length. So we simply mark a length of 10 feet in the joint of the pattern at the solid end, and provide the moulder with a semicircular piece of the same diameter as the plunger, and two or three inches long. Before the pattern is drawn out from the sand, he carries the 10-feet mark across the sand joint both in top and bottom, then withdrawing the pattern, he lays the face of the stopping-off piece level with the mark, and fills up the mould beyond that face with sand (Fig. 193).

Instead of a solid cylinder, let it be one hollow in section, say a pipe 5 inches in bore by 6 inches outside diameter. The stopping-off piece will then take the form of Fig. 194. The half-circle, 6 inches diameter, will, as in the last illustration,

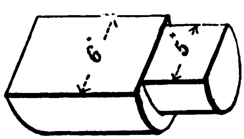


Fig. 194.

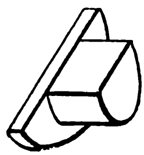


Fig. 195.

fit the mould of the pipe body, but it will have a 5-inch half print screwed upon it. This, when laid in the mould and rammed round with sand, will give both the length of the pipe and the shape and size of its print as well.

If, instead of a plain pipe, we have one double flanged, we should proceed in this way. A pipe, say as before, 6 inches diameter by 12 feet long, has to be made 8 feet long, and at each end of the 8-feet length a flange is wanted. On the pipe body, 8 feet away from one flanged end, we screw a body flange (see p. 107) of the size we want cast on. Then we make a stopping-off half flange and half print that will be dropped into the impression made by that on the body, and there rammed round. Or we may take one-half the flange from the pipe, and, filling up the hole which fitted round the body, screw a print against that, and use it in the same fashion (Fig. 195).

From these illustrations it is apparent that the principle is capable of almost indefinite application. There is, in fact, scarcely a limit to its adaptability. Pattern wheels may have castings made from them either deeper or shallower, without altering the depth of the pattern itself. In the first instance the wheel is *drawn*, in the second *strickled*. That is, supposing the pattern were 3 inches deep, and the castings were wanted 4 inches, the sand would be rammed level with the top faces of the teeth, then the pattern would be drawn up as in delivery, but just to the extent of 1 inch, and the sand rammed level again. The pattern then finally drawn would leave the mould 3 inches + 1 inch = 4 inches deep. Or, in the second case, the pattern being 3 inches, we want the casting 2 inches deep. Then the sand, as before, being rammed level with the top faces, a strickle shouldered to 1 inch in depth is worked around and between the teeth, making a new joint 2 inches from the bottom of the pattern (Fig. 196). Even the outlines of side frames, cheeks, and brackets are

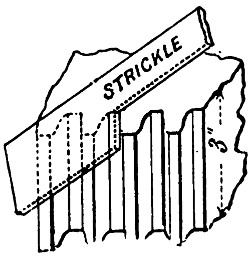


Fig. 196.

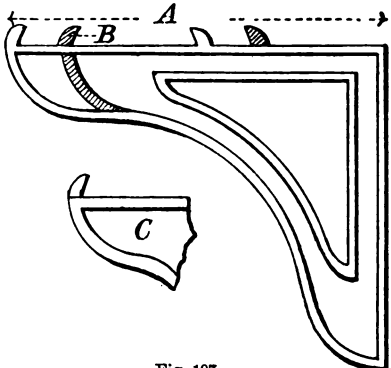


Fig. 197.

altered as occasion arises by this simple method of stopping-off. Thus a wall bracket like Fig. 197, A, would easily be cast like Fig. 197, B, in the manner shown, the shaded parts representing the new pieces put on the pattern which indicate the shorter length required, and the piece C the stopping-off templet for the use of the moulder. In the economy of the trade this principle of stopping-off is of the utmost importance.

Skeleton Patterns.—Loam patterns are economical; but, apart from loam work, there are methods of making some pieces of casting without a complete pattern. Thus, if we wanted a ring somewhat large in diameter, and moreover for a temporary job only, we should make a sweep (Fig. 198) of the same section as the ring, and a foot or so in length. To this we should attach a radius bar, B, in which a hole would be bored corresponding in position with the centre of the ring. A stake, C, driven into the sand would form a fixed centre, around which this would swivel on a hard wood pin or bit of wire, *d*, while the moulder rammed the sweep up a sufficient number of times in succession to complete the circle. Or we may omit the bar, and simply mark two circular trammel lines on a true sand bed, by which to set the sweep.

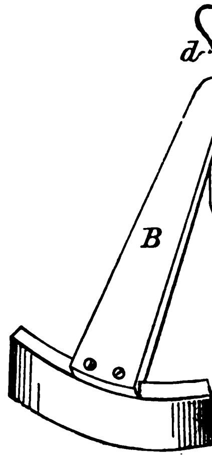


Fig. 198.

As a rule, a whole pattern would not be made for a large rectangular casting, such as a boilermaker's or smith's levelling block. In these cases a frame only would be screwed together (Fig. 199), rough inside, but corresponding outside with the block in length, width, and depth. A level bed would be made on the sand, the frame laid upon it, and the sand rammed round flush with its top edge, and strickled-off level. The pattern would then be withdrawn, its cores put in by measurement, and a plain top box, rammed on the foundry floor and struck off level, would cover the mould over. These are simple illustrations, but the principle is often extended. The cast-iron centres for the wrought-iron truck frames of cranes are made in this way (Fig. 200). The curb ring facing, boss, and bed are strickled

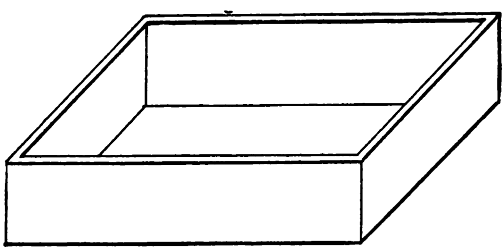


Fig. 199.

in the bottom by a board working round a core-bar, the skeleton pattern frame is rammed around on this, and the top and bottom arms, and middle ribs and boss, are formed by cores.

Neither in making a plated casting is a whole pattern necessary. The familiar form of a tank-plate will illustrate this. A frame is made corresponding in outside dimensions and in thickness with those of the plate, and to this frame the flanges for bolting are screwed. When the pattern is rammed up and turned over, its position is that represented in Fig. 201. The sand within the frame is strickled over level with its upper face. The top box is then placed over it, and upon the level and hard-rammed surface of the frame the

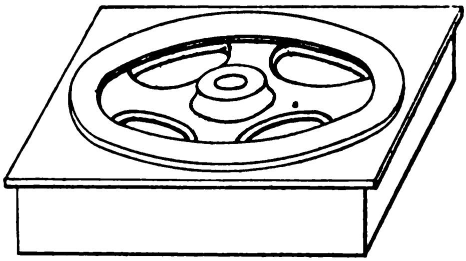


Fig. 200.

top sand is rammed (parting sand of course intervening). The top is then removed, and the sand within the frame is scraped out with a strickle, shouldered to the same depth as the thickness of the plate (Fig. 201), after which the pattern is drawn out. This method is also applied in modified forms

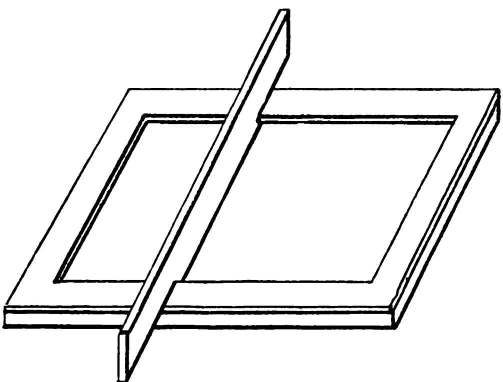


Fig. 201.

to core-boxes as well as to patterns. In making tank-plates in quantity, however, it is usually considered cheaper to make the pattern solid, and so save the cost of strickling each time of moulding. This is merely a question of relative cost, and does not affect the principle.

CHAPTER XXII.

SPECIALITIES—SPECIAL TOOLS.

Dowels.—Difference between those of the Cabinet and Pattern Maker.—Wood Dowels.—Metal Dowels.—Peg and Cup and Plate Dowels.—Methods of putting in.—Rapping Plates.—Lifting-straps.—Centre Plates.—Modes of securing Jointed Patterns in the Lathe.—Long-toothed Gauge.—Radius Finder.—Flange Templet.

THOUGH there are many points of similarity among those trades which employ the same materials of construction, each has, nevertheless, its own specialities—special tools, modifications of tools, and modified methods of working. Cabinet-making, carpentry, pattern-making, and the cognate wood trades have many tools in common, yet each also has its appliances separate and distinct from the others. Likewise, boiler-making, smith's work, engine-fitting, brass-finishing—all have this in common—the manipulation of metals, and a knowledge of the qualities which characterise those metals, besides the possession of some similar tools. Yet each trade, again, is so highly specialised that the man who works in one rarely has a thorough knowledge of the other. Taking this view of the matter, therefore, a few remarks upon the commoner specialities of the pattern-maker's craft in particular will, I trust, be in keeping with the scope of this work.

Dowels.—These are in constant request in the pattern shop. But the dowels of the pattern-maker are used with quite a different purpose from those of the cabinet-maker and carpenter. The latter must hold tightly in the wood; the former simply act as steadies to pieces which have to be left loose in moulding. The purpose of the two being quite distinct, their forms differ also. The cabinet-maker's dowel is a parallel pin fitting tightly and glued firmly into each of the two pieces which are jointed together. The pattern-maker's dowel, on the contrary, fits tightly into one piece only, the other being left so easy a fit that the loose piece will come away with the top sand from the lower part of the pattern. But this does not mean "slop," for too slack a fit would cause overlapping joints and inaccurate work. The fit should be good when the joints are closed up, and only slop when they are separated. Hence the dowel is parallel through one-half only of its length, and tapered like a print through the other half, the first portion being that which is driven home, the second that which retains the temporary loose piece in position.

Formerly, all dowels were made of wood in the pattern-shop —oak, apple-tree, birch—almost any hard wood was used. They were either turned in the lathe or else planed up in lengths in an angle-board, to be sawn off just as required, and the half intended for the loose fit filed taper with a safe-edged file. But in the good shops these have long since been superseded (except where rough and temporary work is concerned) by metal dowels made expressly for the trade. These are vastly superior to the wooden ones, being more accurate, less likely to become broken off or damaged, and consequently more durable. Two forms are shown (Figs. 202, 203),

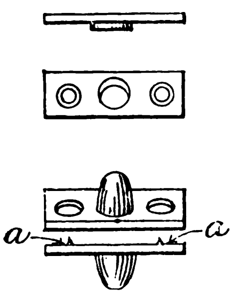


Fig. 202.

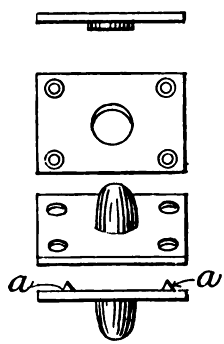


Fig. 203.


Fig. 204.

each of which are made in various sizes. The peg and cup dowels (Fig. 204) are made in brass, and are quickly fixed; but the plate dowels are more suitable for permanent work.

The brass dowels are put in thus. Say we have two pieces of wood prepared for a plain round core-box (Fig. 205). Square over from their two correspondingly true edges, two corresponding lines representing the centres of the dowels, measured longitudinally. On those lines gauge at equal distances from the edges other lines, the intersections of which will be the centres of the dowels. But we do not always want the trouble of squaring edges, neither in all cases is it possible to get a square edge to work from. So a true way and ready is to lay a common pin in the joint with its head covering the spot where we want the centre of the dowel to come, and then

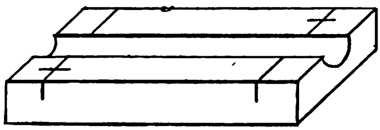


Fig. 205.

to press the upper and lower blocks together. The pin-head will leave its impression on the two blocks, corresponding exactly with one another in position, and these form the centres for running in the centre-bit. Half a dozen or any number of holes may be marked thus if needed, and all perfectly true. This is so good and simple a method as to be preferable to the scribing of lines.

Having the centres marked, bore holes, so that both shank and cup may be driven in tightly. Note that the portion which is driven into the wood is not screwed, as it may appear to be at first sight, but is simply grooved out concentrically. The idea is, that the yielding grain of the wood being forcibly driven out of its natural position by the blow, will afterwards swell out and hold the dowels in position by filling up the inter-ring spaces.

The plate dowels are put in thus. On the underside of the female plate there is a ring (see figures). In the joint of one of the pieces of stuff to be dowelled bore a centre-bit hole, into which this ring shall fit tightly, the hole having a depth slightly greater than the length of the dowel-pin itself. Dropping the ring into this hole, scribe round the edges of the plate, remove it, and cut a recess to that size, and equal to the thickness of the plate. Drive in the plate, see that it is flush with the surface of the joint, or, even better, just a shade under it, and screw in place. Then the male plate is dropped in, the top half of the pattern lowered over it steadily into required position and pressed downwards. The two points or nibs, *a*, *a*, which stand out from the back, will then leave an impression in the top of the pattern, by which we can, when turned over, set the plate in that half and mark its exact boundaries. Its recess will then be cut, into which it will be screwed, and if done carefully no fudging will be necessary to insure a proper fit between pin and hole.

Rapping Plates.—A pattern must be subjected to the process of "rapping," else on attempting to pull it by main force out of the mould, all the bounding edges of the sand would cling to it and become broken and torn up. But rapping loosens the pattern by slightly thrusting aside the sand which is in close contiguity to it, and, so to speak, clearing its way. A hole is bored in the pattern, the pointed end of a round bar is thrust into this hole, and the bar is then struck sharply with a hammer on all sides in succession. Now this, as may be believed, is very destructive to the pattern, although essential to the moulding. So plates of wrought or cast iron have long been substituted for the hole in the wood, the plates being let into the pattern flush with its top face.

But a few years ago, perhaps a dozen or more, plates made of malleable cast iron became a speciality, and have gradually superseded the clumsier, and in the end dearer, home-made productions, so to speak, of the shop. They are neat, and are made in several sizes, of rectangular form. In most cases they contain provision both for rapping and lifting. Figs. 206, 207 show two different forms of these plates, *a*

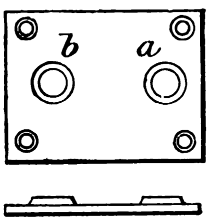


Fig. 206.

Fig. 207.

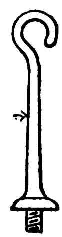


Fig. 208.

being the plain hole for rapping, *b* the tapped hole for the reception of a lifting-screw (Fig. 208). The plates are let in similarly to dowel-plates, and are secured by the longest screws it is convenient to use.

Lifting Straps.—When a large pattern has deep sides, a great amount of friction is set up between it and the sand, and it is lifted out with the foundry crane. In most cases of this kind plates would be useless except for rapping, because the strain put upon them in overcoming this friction would tear them away from their attachment in spite of screws. Then we put on lifting-irons or lifting-straps (Fig. 209). These are pieces of thick hoop-iron or thin wrought-iron

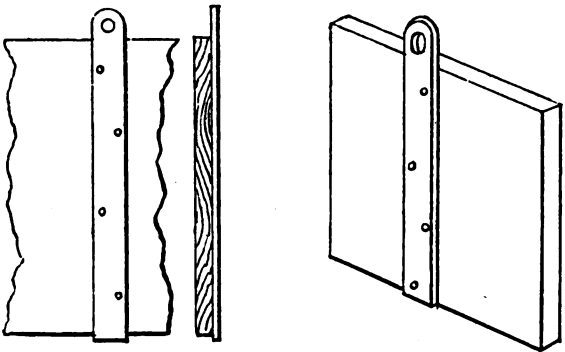


Fig. 209.

bar screwed all down the side of the pattern, and bent round at the bottom to a right-angle. The upper end has a hole drilled to receive a rod for the hook of the crane. By making these straps somewhat thick, say ⅛ inch or $\frac{3}{16}$ inch, they can be made to fulfil another useful purpose in certain cases—viz. they will keep the pattern straight throughout its depth—an obvious advantage where thin stuff is otherwise scantily stayed. As they are used only with deep patterns, the fact of their standing out from the face of the wood to a distance equal to their thickness is attended with no inconvenience, because in such patterns either the middle or the outside of the mould must in most cases be lifted away for the purpose of rendering their faces accessible for cleaning up. Then the impressions left by the straps are filled with sand and levelled.

Centre Plates.—These are indispensable to the pattern-maker. They are used for the purpose of securing the two halves of a dowelled pattern while it is being turned in the lathe. Those illustrated in Fig. 210 are used for work of small diameter, and the claws, *a*, are sufficient to insure security while turning, but for larger work such could not be depended upon, and plates secured with screws (Fig. 211) are necessary. When centre plates are not used, as in small work, the stuff is secured with wood screws

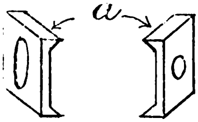


Fig. 210.

(Fig. 212), which figure shows a roughed-out piece of stuff ready for the lathe, or, when the stuff is large, with "dogs" or

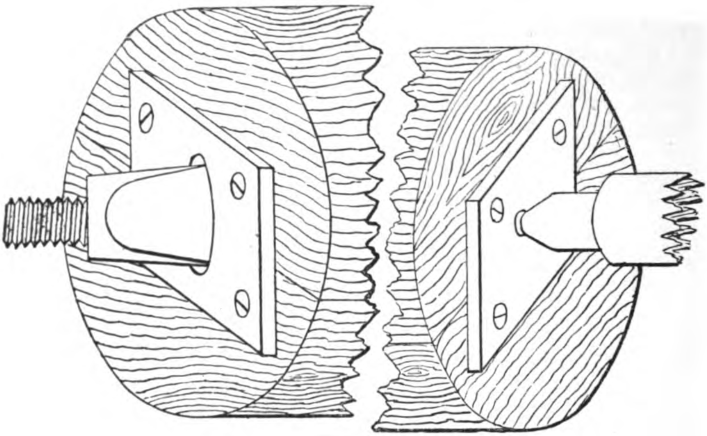


Fig. 211.

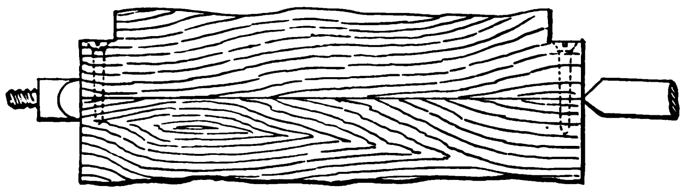


Fig. 212.

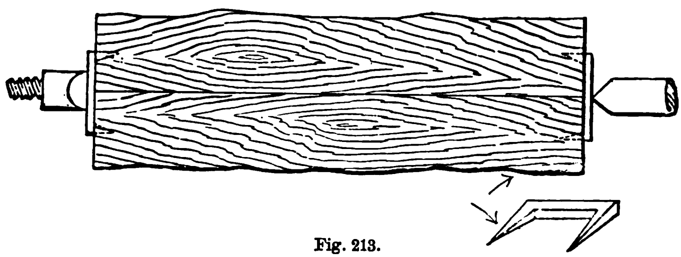


Fig. 213.

"staples" (Fig. 213). But, even when it is not jointed, centre plates should be used with large work, because, without them, both fork chuck and dead centre work into soft yellow pine to a greater depth than is desirable, thereby increasing friction, and sometimes causing the pattern to run out of truth before it is finished.

Long-toothed Gauge (Fig. 214).—This is in constant use in the shop. In gauging quick sweeps to parallel widths, or in gauging parts not on the same level, this is a most valuable tool, as useful in its way as the trammel with an

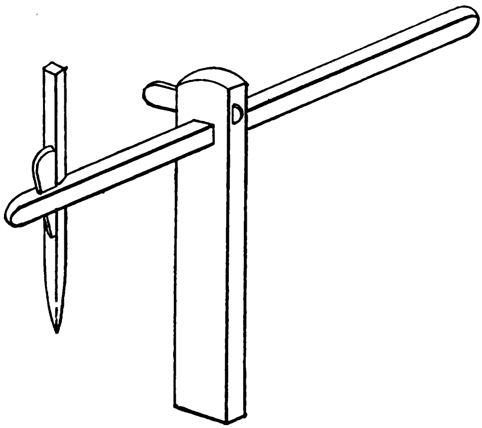


Fig. 214.

adjustable leg. The scribing point is capable of adjustment, and will gauge anywhere within the range of its length, 4 inches or 5 inches. One face of the stock is flat, the other rounding.

Centre Square or Radius Finder (Fig. 215).—A useful home-made article. It is made use of for the purpose of finding rapidly the centre of a disc, without rule, compasses, or geometry. On a piece of mahogany $\frac{3}{16}$ inch thick draw a circle, say, $3\frac{1}{2}$ inches diameter; through its centre draw lines intersecting at right angles. Cut to one of these lines to a little below the centre, A; drive two turned pins, *a*, *a*, through, on those points where the other line cuts the circle, and finish the edges to taste. When the edges of the pins are slid round the circumference of a disc, the edge A always points to its centre. The intersections of lines drawn from opposite sides of the disc will indicate the centre point. The limits of its adaptability range between a diameter somewhat greater than the distance apart of the pins and one twice the length of the stem. This tool has been improved upon in an American article costing about 12s.

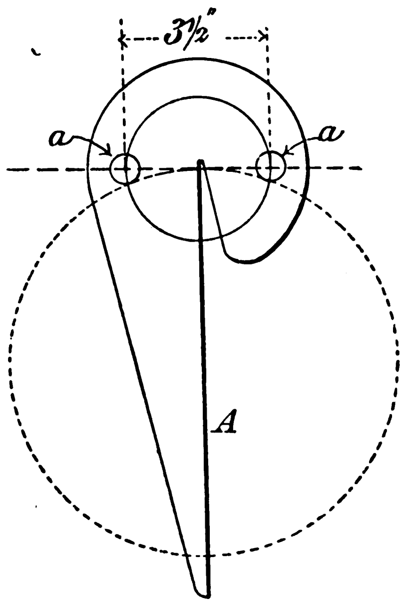


Fig. 215.

Among the numerous little time-saving appliances of the trade I shall mention one more. Every pattern-maker is aware of the difficulty of screwing body flanges quite accurately on pipes, by set-square or trying square, especially when the edges of the patterns have become damaged by long usage. A very simple article by which the difficulty is minimised is shown in Fig. 216. It consists simply of three strips of wood fastened together, with sides parallel, and ends as square as they can be made. Fig. 217 shows the templet in use. Its face is held against

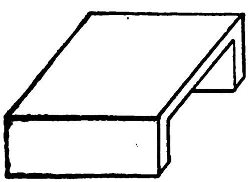


Fig. 216.

the face of the flange, while the screws are run in, one inside edge being of course in contact with the edge of the

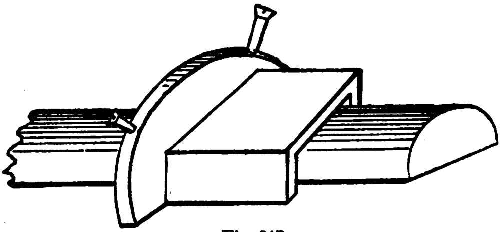


Fig. 217.

pipe itself. Half-a-dozen of these, ranging from 2 inches to 12 inches between their sides, will embrace all pipes within those limits.

CHAPTER XXIII.

CHAIN BARRELS.

Various Kinds of Barrels.—Plain and Spiral.—Barrels made from Loam Patterns.—Mode of Striking-up.—Barrels made from Loam Moulds.—Striking-up.—Right and Left-handed Spirals.

MANY barrels are made quite plain around their circumference, and then the chain can only lie at an angle (Fig. 218). The disadvantage with these is that the links are apt to override

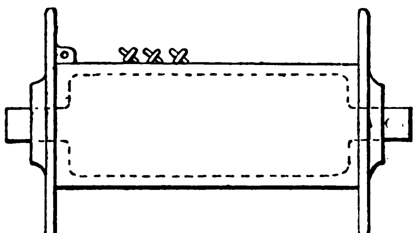


Fig. 218.

one another, with the result of straining the chain when they are jerked into the normal position by a load pulling at them. Barrels grooved spirally to take the links in flat and vertical positions alternately are made with the purpose of obviating this dangerous liability (Fig. 219). Barrels also not grooved with deep link recesses, but simply hollowed out spirally to take the links in angular position, without the danger of overriding, are also made (Fig. 220).

The pattern of the plain barrel presents no difficulty. The remarks made in reference to the building up of plain cylinders and columns will apply to these barrels. If small, they are made of solid stuff, jointed and dowelled of course; if large, they are "lagged up" (p. 61). The flanges and their bosses are turned separately and screwed on the ends, and the prints for the hole for the barrel-shaft are fastened outside of these again. The spiral, whether it be a groove or a hollow, is marked out by points of equal division in the manner

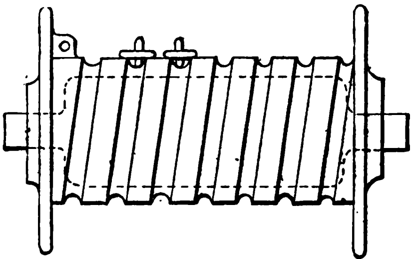


Fig. 219.

adopted when making pattern screws (see p. 175). Thus if the pitch of the screw on our barrel were 3 inches, divide that into, say, a dozen equal parts, and divide the circumference into precisely the same number. Through the successive in-

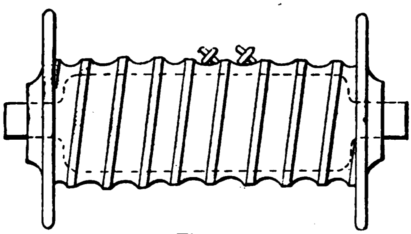


Fig. 220.

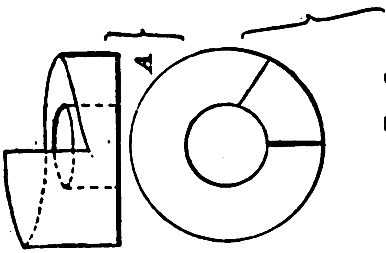
tersections carry the thread. Mark another line parallel with the first for the width of the groove, and work with gouge and chisel. The central core is struck by a loam-board.

But the cost of patterns of this kind, except where the same type of crane is being constantly repeated, bears too great a proportion to the cost of the castings. In such cases a plain barrel already in stock, of the diameter of the bottom of the groove, is sometimes utilised by having lead strips cast to the section (Fig. 221), and bent round and fastened with screws. Yet this is a clumsy method, and not to be recommended. A better way, if the barrel does not exceed 20 inches or 24 inches in diameter, is to make a good *loam pattern* (see Chap. XXI.), which, if well made, and protected with a coat of tar, will

Fig. 221.

stand several mouldings before it becomes rotten. If the barrel exceeds these diameters, a *loam mould* (see Chap. X.) is our only choice.

To get the spiral groove, a good deal of rigging up is required, after which the process is as simple as possible. Let us take the loam *pattern* first in order.



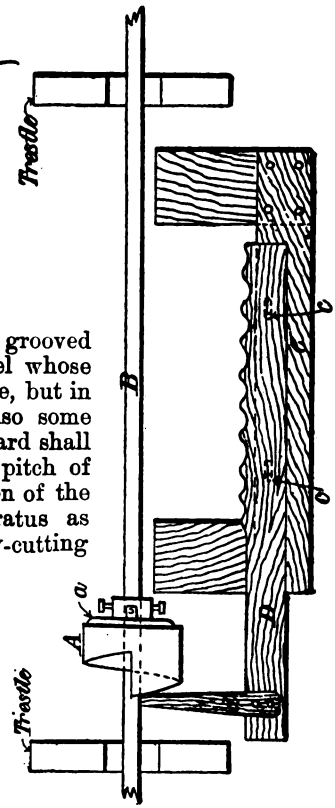


Fig. 222.

We require a loam-board grooved along its edge like the barrel whose pattern it is intended to strike, but in the reverse way. Evidently also some arrangement by which the board shall travel a distance equal to the pitch of the screw during one revolution of the core-bar; in fact, an apparatus as regular in its motion as a screw-cutting lathe. But it would be preposterous to think of fitting up change-wheels to a core-bar, so we devise some simpler but equally (for our purpose) effective method. Fig. 222 shows the arrangement.

A is a block of wood turned to any size, say, a foot in diameter, and bored to fit loosely over the end of the core-bar, B. One face of this is cut to form the face of a screw of exactly the same pitch as the spiral on the barrel. Two pieces of paper, equal in length to inner and outer circumferences respectively, and cut to the pitch—that is, tapering from 3 inches to nothing on their lengths—

and glued round the inner and outer diameters, give by their slant edges the lines by which the face of the block is to be worked. On the back of the screw-block a face-plate of iron, *a*, is attached, and by means of the set screws in the boss the screw can be adjusted truly on the bar.

The loam-board consists of two portions—the lower, C, which strikes a loam body ¼ inch or thereabouts less in diameter than the base of the grooves, and the ends, the bosses, and the prints beside, not shown. Over this comes the grooved board, D, which slides upon the bottom one by means of two hardwood pins, *c*, *c*, working in slots, which slots permit of its motion in a rectilinear direction over a space equal in length to the pitch of the screw.

Now all is clear enough. After the loam body is struck up by the bottom board, the latter is of no further service save as

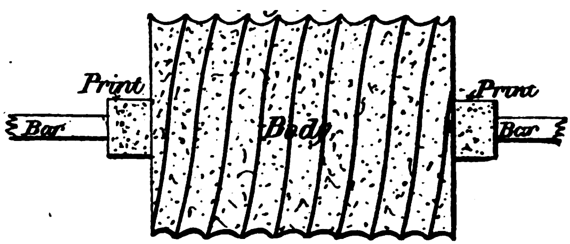


Fig. 223.

a base for the spiral board. It is accordingly drawn back to clear the points of the screw, and the top board dropped into place by means of the pins, in a position corresponding with the commencement of the screw-thread. A boy then turns the handle of the core-bar, and while the core-maker daubs on the loam, another boy steadies the board whilst it is being pulled along by the screw A through the medium of the tongue piece *d*, working against the screw face. Immediately that it gets close to the extreme of the screw pitch the boy at the handle turns more slowly, until the shoulder of the screw is reached, when boy number two slides the board sharply back to the commencement of the thread once more. After this process has been repeated, say, eighteen or twenty times, the loam pattern screw is neatly finished, and is ready to go into the stove to be dried. The loam pattern, when struck up, has at this stage the appearance of Fig 223. The flanges and facing bosses are made of wood, and bored to fit the loam prints.

Very large drums are so seldom in demand, that usually one casting alone is wanted at a time. Then, if the diameter will permit of a man standing upright within it to work, we make a loam mould. This requires a special rig-up, the same in principle, but differing in detail, from that last described. The same guiding-screw will be used, but it will be laid in

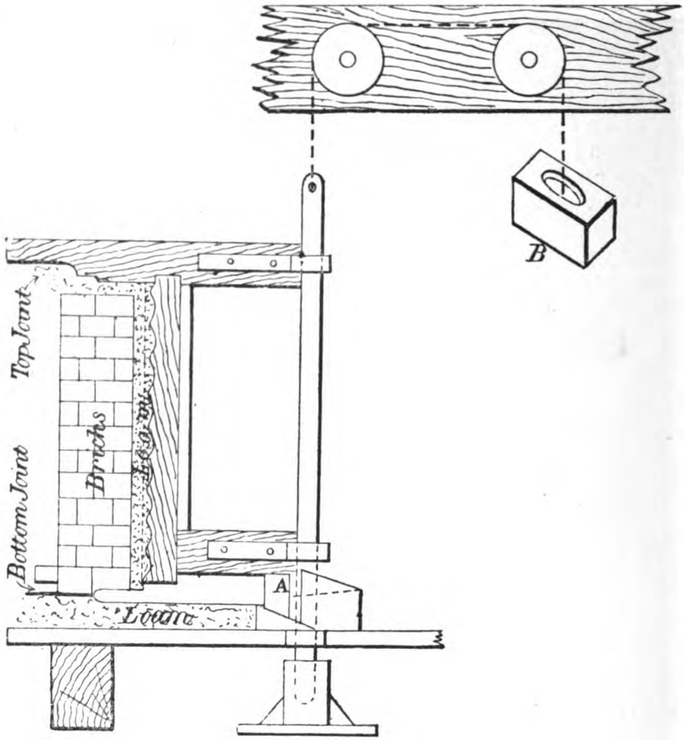


Fig. 224.

the bottom of the mould in a recess specially struck for its reception by the bottom loam-board. The striking-board also, instead of being cut reverse to the screw grooves, as in the last example, will be cut like them; because, in this case, it has to strike the actual mould and not the pattern itself. The apparatus for striking will still be made in two, but will differ from the last in these particulars. First, there will be the under plain board for striking the loam body, not as in the last, ¼ inch smaller than the base of the grooves, but the conditions being reversed, ¼ inch larger than their tips. Then the second board, its edge cut to the shape and pitch, will not work in slots, but will be screwed to the first-mentioned one, and the necessary vertical movement will be accomplished by another device. Fig. 224 represents the apparatus rigged-up ready for striking the spiral. The top joint will have been struck before the screwing-tackle is put in.

A is a block of wood carrying a small iron roller, enlarged at Fig. 225, which runs on the face of the guiding-screw, the block being fastened firmly to the bottom bar of the striking-board with wood screws. B is a counterpoise which, by taking the weight of the board and striking-bar off the roller, allows the whole affair to run with very little friction, and leaves the moulder free to give his attention to the loam without much expenditure of muscular effort. When the board drops from the top to the bottom of the guiding-screw at the end of each revolution, a groove will necessarily be cut in the loam equal in width to the thickness of the board; this the moulder will fill up when wet, and dress off afterwards when dried. With this

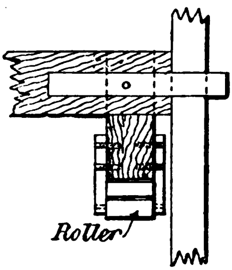


Fig. 225.

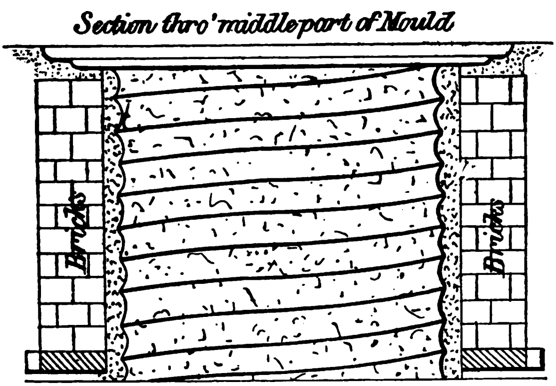


Fig. 226.

exception, the action is quite automatic; the moulder has merely to move the board around, and see that the loam he throws against its face is of the proper consistence. Fig. 226 shows half a section of the middle part of mould. In cranes of heavy construction it is common to have two chains winding at once, one from each end of the barrel. This means a double spiral, right and left-handed (Fig. 227), and, of course, two guiding-screws, one cut to a right-hand, the other in a left-hand direction. The grooved board also will be only half the length of the other, and will strike the two screws distinct.

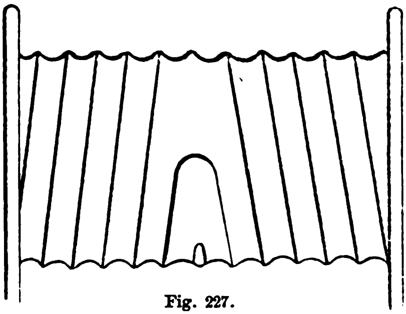


Fig. 227.

Thus, say the screw commencing at the centre of the barrel and running upwards is right-handed, while the other running downwards is left-handed. The grooved board will be screwed on first for the top screw, and the right-hand guiding-screw put in the bottom. When it is struck, the grooved board will be removed to the bottom, and the left-hand guiding-screw put in. The bottom screw is struck last to prevent its receiving damage from the tumbling down of loam from above.

The making of the lugs, or recesses, as the case may be, for the attachment of the chain or chains is too simple a matter to call for comment, and the making of flanges and boards, top and bottom joints, has already been described.

CHAPTER XXIV.

CHILLED WORK.

Theory of Chilling.—Trolly-wheels.—Curve of Disc.—Chill.—Top Box.—Roller.—Jointing of Chill.—Wheel Naves.—Clips.

THE art of chilling castings properly is only to be acquired by long experience and observation. The theory is, that by the chilling of a casting the separation of the graphite from the iron is prevented, and combination takes place instead. The essential thing is so to mix various classes of iron together that a chilled face penetrating to any required depth may be assured. Consequently, it is somewhat of a trade secret; those who know how to chill keep the results of their experience to themselves. But, as regards the pattern-maker, the only knowledge necessary to be imparted is how to make due provision for patterns whose castings have to be chilled.

A chilled surface results when molten iron is run against a cold metallic mould. The crystals of metal invariably arrange themselves at right angles with the cold surface, and they become white, hard, and of a steely nature. The regularly crystallised portion may extend from ¼ inch to ¾ inch in depth, and presents a most characteristic section when broken along the course of the needle-like crystals (Fig. 228).

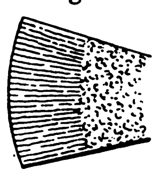
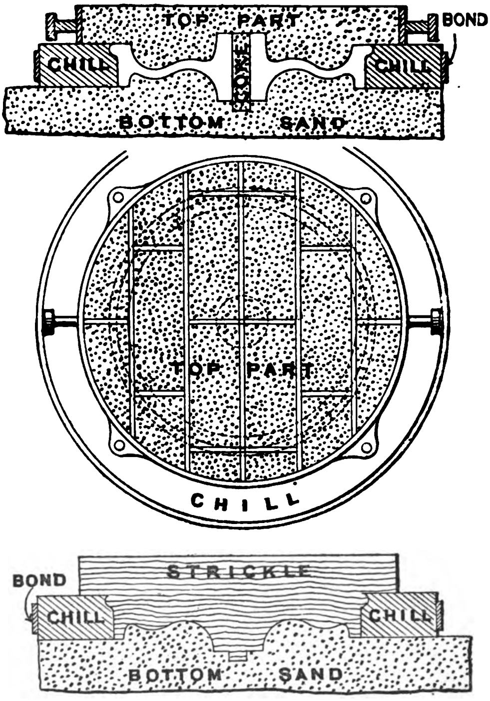


Fig. 228.

Take a simple illustration in the first place. We want to chill a trolly-wheel so that it may resist the grooving action of the rail for a long time. We could not possibly chill a thin wheel without weakening it very much; therefore it should be substantially proportioned *round the rim.* Properly, too, it should be a plated wheel. We have several times had occasion to refer to the internal stresses set up in cast iron through the irregular cooling of different parts, and in particular when treating of strap pulleys (p. 84) we mentioned that the curved arm was adopted with the view of lessening the liability to fracture arising from that cause. For the same purpose when we chill wheels, we curve, not indeed the arms, for arms are not so suitable here, but the discoid centre (Fig. 229). The rim is chilled almost immediately that the fluid metal comes in contact with the cold iron ring, and consequently it has no further contractile power. But the centre



Figs. 229, 230, 231.

being yet red-hot, goes on contracting after the setting of the rim. In a small wheel the natural elasticity of the iron will prevent any evil effects arising from this source, but a large one must either inevitably break or be liable to fracture at any future time through internal tension and stress. By imparting a large amount of curve to the disc the wheel is safe, provided, of course, that the metal in the boss is not in excess, and that the proper mixtures are assured. The disc will accommodate itself to molecular stresses, and lose some slight portion of its curvature.

First in order we take the pattern. There will be no difference between this and any ordinary pattern of the same class. Build up in segments as usual and turn to templet. Then follows the chill. It is seen in section in Fig. 229, and in plan in Fig. 230. It is made wide, and bonded, otherwise it is liable to burst. Six or eight inches of metal in the chill will not be too much for a wheel of two or three feet in diameter. It is accurately bored to the same shape as the wheel rim. As the rim alone needs chilling, the two faces of the castings are made with a sand mould. The bottom face will be strickled, the strickle working on the edge of the rim (Fig. 231). After having strickled the bed, the pattern will be laid upon it, and in the chill. Then the top box will be placed in position, and secured by its pins dropping into holes drilled in the top face of the chill, while the upper face of the pattern is rammed up. Or, instead of bedding in the sand floor, a bottom box can be used, and the pattern turned over. The mould, when cleaned and put together, will have the sectional appearance of Fig. 229. Fig. 230 shows it in plan. The rim will, if the founder makes his mixtures properly, be chilled as hard as highly-tempered steel to a depth of from ¼ inch to ¾ inch, as desired.

Suppose, however, that we have to make provision for chilling a roller for a turntable or for a crane, as shown in Fig. 232. It is quite clear that although the metal could be run into the chill, the casting could not be got out; therefore in this case we must part our chill. One way to part it would be through the centre in the plane of the wheel (Fig. 232, *a*, *a*), moulding in other respects as in the last instance. This would answer the purpose, and the only objection to it would be the "fin," as it is termed, or thin film of metal which forms at the joint. This could be ground off, however. Or the chill could be jointed in three in the line of the wheel axis, and fastened with cottars passing through lugs. Of the two, the latter is, perhaps, preferable, though a little more expensive to construct (Fig. 233).

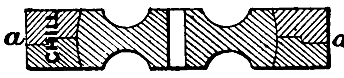


Fig. 232.

Some castings are chilled through their inner diameters. A wheel nave will illustrate how this may be done. Common wheel naves, with tapered holes for tapered axles, are not bored; yet it is necessary that they should be smooth and truly circular, and durable beside. In order to effect these ends, a chill is often used in preference to a common core.

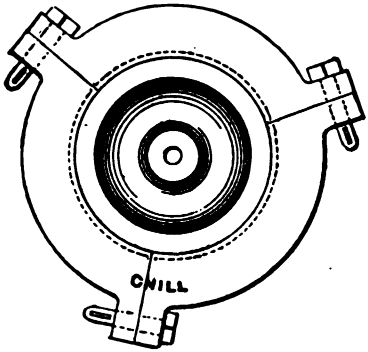


Fig. 233.

Having the pattern presumably with its prints true, and the chill with ends corresponding exactly with the prints on the pattern, the one essential is that the chills shall always occupy precisely the recesses formed by the prints in the mould. This could not be insured in prints formed in sand, because the weight of the iron chill would displace the more yielding sand to a certain extent. So iron rings, bosses, or clips, it matters not which, are cast and bored to fit alike around the pattern prints and the ends of the chill, and these being either rammed up in the sand, or fastened to the top and

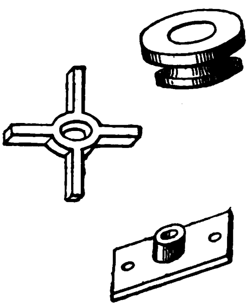


Fig. 234.

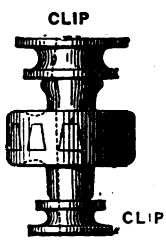


Fig. 235.

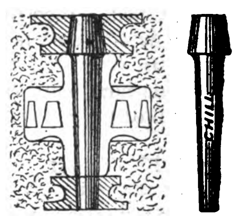


Fig. 236.

bottom respectively of the moulding box, retain the chill in place. Fig. 234 shows different forms of clips. Fig. 235 shows them attached to the pattern. Fig. 236 shows them round the chill.

CHAPTER XXV.

SCREWS.

Principle of the Screw.—Diameter.—Pitch.—Striking out.—Entire Patterns.—Fitting the Segments.—Working to Shape.—Pile Screws.—Propeller Screws.—Marking out.—Pattern Blades.—Loam Screws.

Screws will range from a few inches in diameter up to several feet. They will contain several revolutions, as in those for corn elevators and brick machines; or a single revolution only of the blade, as in pile screws; or fractional portions of two three, or four helices, as in propellers. We can also mould them from patterns, or strike them up in loam. To a young hand a screw appears a most difficult task—a veritable donkeys' bridge, the *Pons Asinorum* of his craft. How to get the necessary lines is by no means clear, nor, having got them, how to work the blades. But if the fundamental principle of the screw be borne in mind, viz. the development of an inclined plane around a cylinder, no real difficulty need be experienced in work of this kind. Details will vary, and a considerable degree of accuracy will be requisite, but a screw is only a screw after all, no matter how it may be modified.

The diameter of a screw is measured across the tips of the blade (Figs. 237, 238). The pitch is the distance between the

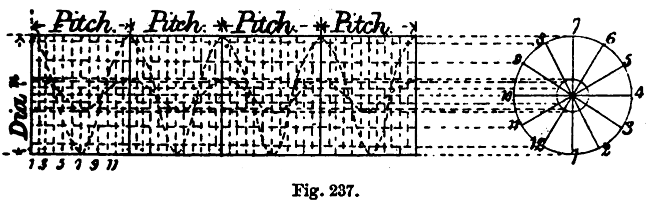


Fig. 237.

centres of the blade when it has made one revolution (Fig. 237). So that a piece of paper shaped like an inclined plane, equal in length to the circumference of the screw, as wide at one end as the pitch of the screw, from thence tapering to a point at the other end, will, when wrapped round a cylinder

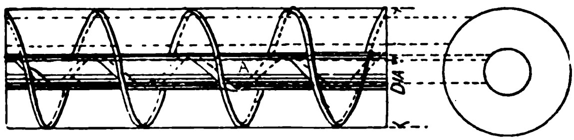


Fig. 238.

of the proper diameter, form a helix around its circumference. Similarly any number of revolutions could be formed by describing corresponding lines on a sheet of paper long enough

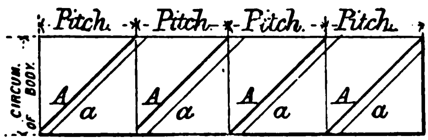


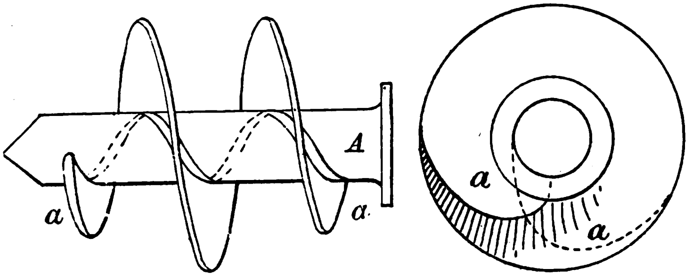
Fig. 239

to embrace the total number required, such lines to fulfil the condition stated above, and to run parallel with one another (Fig. 239, A, A, A, A).

But this, though a correct and ready method in the case of small screws, would not be quite so practicable with those of large diameter which are not cut from a solid cylinder. Some other method is desirable, and the following answers for a screw of any diameter, and also for the projection of the screw on the drawing-board.

Divide both the circumference and the pitch into the same number of equal parts (Fig. 237)—10, 20, 50, it matters not, so that they are equal; but the greater the number of divisions, the more accurately will the screw be lined out. Through the successive intersections of these lines draw a diagonal, right or left handed, as required, and this will represent the line of the screw thread—either its edge or centre, whichever we choose to elect (Fig. 237).

If we had to make a screw either with one or with several revolutions and of small diameter, we could cut it out of the solid stuff, as we did in the case of the worm (Chap. V., p. 34). But such a course would be open to this objection—that the fibres of the grain would be no longer than the thickness of the screw blade, and our pattern would become damaged or broken by a very slight amount of ill-usage. Hence a better way—the correct way, in fact—is the following. First joint, dowel, and turn up the body of the pattern, *i.e.* the solid portion round which the helix turns (Fig. 238, 240, A, A). Evidently the pitch of a screw at the base must be equal to the



Figs. 240.

pitch at the point. So we mark our inclined planes diagonally across, uniting the lines which represent the pitch, with the edges which complete the circumference, on a piece of paper of the breadth of the screw body, and of length equal to its circumference (Fig. 239, A, A, A, A). Parallel with these lines, and at a distance from them equal to the thickness of the screw at the root, we mark other lines, *a*, *a*, *a*, *a*, and then glue the paper round the turned body. The space inclosed by these parallel lines represents the width of a groove which is to be channelled out about $\frac{3}{16}$ inch deep, with saw, chisel, and

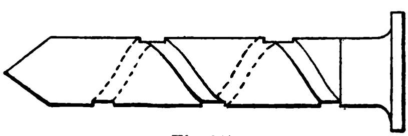


Fig. 241.

templet, to receive the actual screw. When the groove is cut the body will have the appearance of Fig. 241, which represents the body of the pile screw (Fig. 240).

Then for the actual thread, get out a number of segments roughly, like miniature propeller blades, long enough to reach from the bottom of the groove to a little beyond the screw tip, say $\frac{1}{4}$ inch, and a little thicker than the thickness of the screw at the root or base. The width will be immaterial—say a sixth of a revolution each in a small pattern, a tenth or a twelfth for a large one. Let the grain fibres run towards the centre of the screw's diameter to afford the greatest strength (Fig. 242), which represents three such roughed out blades. Each of these pieces must now be fitted in succession with gouge and chisel in the grooves previously cut, and the centre line of each piece should stand approximately square with the axis of the screw body. As these are fitted in succession they must be held in place by means of screws run in from the *joint* of the body. When the desired revolution or number of revolutions is complete, replace the body in the lathe, and turn the edge of the blade to the proper diameter, holding the tools with a firm grip to avoid a smash.

Fig. 242.

This being done, mark on a strip of wood the number of divisions into which it is intended to divide the pitch (Fig. 243); lay this on the lathe rest, and with a timber scribe set off corresponding lines on the revolving pattern. Then divide the circumference into the same number of equal parts as that into which the pitch is divided. Through the successive intersections of these lines draw a helix by means of a narrow blade of thin steel bent around the edge (Fig. 244), which represents the pattern at this particular stage. Previous to marking these divisions, especial care should be taken that we start square with the body. A good way to begin at right angles is to take the pattern out of the lathe before marking out the point of the thread, unfasten the joint, and mark a centre line on the blade *in the joint* with a square. This produced to the outside will form a correct starting-point for the subsequent dividing out.

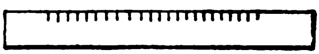


Fig. 243.

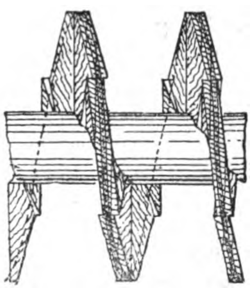


Fig. 244.

The thickness of the screw at the tip will be pricked with compasses and marked equidistantly from the centre line, using the bent steel, as before, to run the lines round. The segments forming the helix will then be all unscrewed at the joint, and one by one worked to shape. This simply consists in cutting *straight* outwards from the thickness of the root, given by the width of the groove, to the thickness at the tips last marked (Fig. 245). A rebate plate, slightly rounded on the face, is the best tool for this purpose, and the work must be tried with a straight-edge from time to time, to be assured that every line running to the centre is straight, and not rounding or hollow. Clean up with glasspaper and replace in groove.

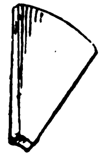


Fig. 245.

If our screw be a small one, say of not more than 10 inches or 12 inches in diameter, these blade segments can now be finally and permanently fixed in place. For a small screw, even though it have a good many revolutions, can, if worked carefully, be drawn, or rather screwed, out of the sand by a spiral twist. But if the screw be one of two or three feet in diameter, the friction of the sand against its sides is much too great to allow of this. In such a case each segment must be drawn separately. This is only possible by allowing the radial joints full freedom to slide over one another; hence screws and brads cannot be used to keep those joints flush in the mould. Yet they must have some steadiment during the process of ramming up, and this can be afforded by an oblong dowel at the tip of the thread (Fig. 246). Each segment piece which contains the dowel-hole can then be drawn out, followed by the piece containg the dowel. The screws in the joint of the body retain the segments in their grooves during ramming up. After they are drawn, the body is lifted out and the segments follow singly.

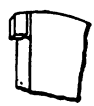


Fig. 246.

The taper of the pile screw (Fig. 240, *a, a*) is given after the screw is worked. It is marked round with a pencil, the eye judging of its shape, or the entire circumference may be divided into a number of equal parts, and in each division, beginning with the first, a corresponding division will be pricked, proportional with the required amount of taper.

In making the pattern for a propeller screw, precisely the same principles of design will guide us as in the previous case, but our mode of working will be greatly modified.

Say we have to make a common screw of 6 feet diameter and 12 feet pitch, by pattern. It may be two, three, or four-bladed, that is, it will contain segmental portions of two, three, or four helices. Our first care is to strike it out. Fig. 247 shows a three-bladed propeller, though not a working drawing; for in practice it is not necessary to strike out the whole screw.

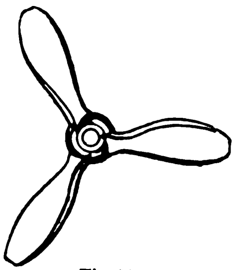


Fig. 247.

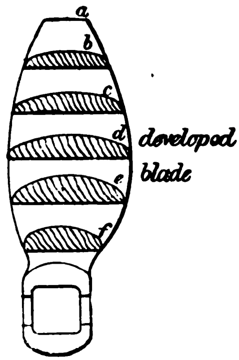


Fig. 248.

All we need take is some aliquot part of the circumference, and a corresponding proportional part of the pitch, from which to get our data. Usually we want the angle at tip of screw, and a single developed blade with a boss section. The blade is developed as shown in Fig. 248 in order that the pattern-maker may prepare his templet strips for the guidance of the moulder, those strips corresponding in shape with the sections drawn across the blade. The angle at tip is required so that a templet may be cut for the building up of a pattern blade, or a sheet-iron guide made for the striking up of a loam bed. Imagine the circle formed by the tip of the screw to be unrolled—that is, take the circumference of the circle, in this case 18 feet $10\frac{1}{16}$ inches, and let that form the one side of a right-angled triangle (Fig. 249), the pitch of the screw, 12 feet, being its base; then the angle the hypothenuse will make with the side will represent the angle of the tip of the screw.

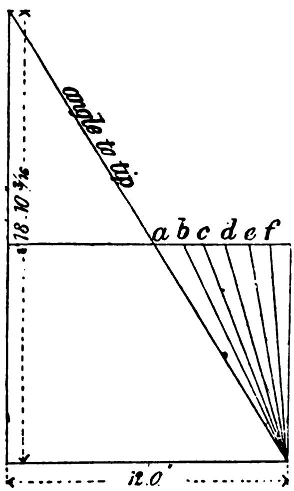


Fig. 249.

This need not, however, be drawn to full size, since in equally proportioned triangles the corresponding angles are equal to one another. So we can make it to any convenient scale, and measure upon it the actual breadth of the screw blade, and divide into as many parts as we divide the radius of the screw into, *a*, *b*, *c*, *d*, *e*, *f* (Fig. 248). These lines will represent the respective angles made by the screw sections at those points.

When a pattern blade is made, it is built up in overlapping strips, as shown in Fig. 250. The strips, it will be observed, are planed to a uniform thickness of ¾ inch or 1 inch, so that when glued together their squared edges form an exact guide for the dressing off to shape. Work from end to end with planes, remembering, as before, that every line running from centre to circumference is straight. If the pattern blade is to be used for casting an entire propeller, the most convenient way of doing so is to make a core-box, put the blade into it, and make as many cores as we require blades. The thing to be noted is that the angle at the segmental boss is suited to the number of blades, 90° for 4 blades, 120° for 3, &c. If a core-box is not used, the blade is attached to a centre bar, and rammed up as many times as there are blades in the propeller. Movable top plates, or drawbacks, are used to carry the sand over the blades.

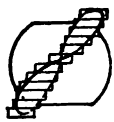


Fig. 250.

In striking up screws entirely of loam, templets of sheet-iron are required, somewhat longer than the blade of the screw at its widest, and deep enough to take the amount of inclination which the pitch gives to each blade. The lower edge being supposed to remain truly horizontal, the top edge is cut to the angle of the pitch, and the plate then bent between rolls, to a circumference somewhat larger than that of the screw tips, is set in position around the bottom plate, and held upright by stakes, or other suitable contrivance, driven into the foundry floor. Then, on the building-up plate and underneath the places which the blades are to occupy, the moulder bricks up three sloping beds, filled in with ashes for the escape of the gas, and covers them with loam struck to shape either by a board working round a central bar, or by a straightedge working across from an inner to the outer templet. The pattern-maker now has to provide outline and sections of blades. The best way to get the outline is to make a templet from the drawing, either in tin, brown paper, or thin wood, and to mark its shape on the loam with a scriber passed around its edges. For the sections, get some strips of wood cut to the respective cross sections of the screw (Fig. 248), or, better still, strips about $\frac{3}{4}$ in. thick cut to section, but cast in lead, and bent each to the curve of the radius at its own particular section. These are set upon the loam face in their proper positions, and their purpose is to afford a sufficient guide to the moulder in getting the proper blade sections. This he does by filling in the interstices of the strips with loam or sand, and strickling it off level with the curved upper faces of the same. The central boss is either made in loam or wood—usually the former. Parting sand being strewn on the blade surfaces, the tops are rammed up in green sand, or as is usually the practice in large foundries where a stove is available, in loam, to be afterwards removed and dried. The templet strips, and their interlying loam, when taken away, leave the bottom face clean, and ready to receive the dried top parts for final fixing and casting.

CHAPTER XXVI.

FOUNDRY REQUISITES.

Moulding Boxes.—Their Proportions.—Details of Parts.—Turn-over Boards.—Plain Boards.—How used.—Recessed Joint Board.—Boards for Gutters.—Plate Moulding.

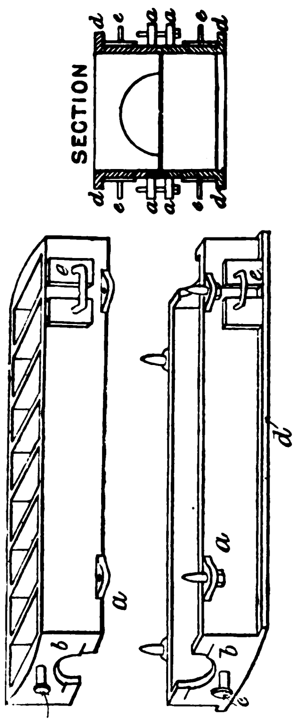
MOULDING boxes or "flasks" are rough articles which any one can make; yet, like everything besides, if one were told for the first time to make a pattern for one of these, he would be in doubt what proportions to give to it.

In the first place, then, the size and shape of the box will be decided by that of the pattern which has to be moulded in it. There should be two or three inches of sand on each side of the pattern in the narrowest portions, and from three to six inches on top and bottom—less in the case of small boxes, more in that of larger ones. It is most essential that a box should be rigid, even if that involves more cost in metal and some extra ramming up of sand. There is an immense fluid strain on a large moulding box when the metal is being run in = head × sp. gr. × superficies of mould. Also in the lifting about and turning over of the box, with its weight of contained sand, there are considerable straining forces at work. A flimsily proportioned box will spring, causing portions of sand to become loosened, to the endangering of the mould and the casting. The liquid pressure of metal will also tend to open its joints and make the casting disproportioned. For these reasons the metal in a moulding box should be heavy in proportion to its size. A box soon pays for itself, and the metal is always worth its first cost.

Usually the top part of the box has vertical bars, and, unless in cylindrical work, the bottom part flat bars. In boxes for cylindrical work there are vertical bars in both top and bottom. If there is a middle part it is usually without bars. The vertical bars should be brought within about $\frac{3}{4}$ inch of the joint edge of the box, and within the same distance of the pattern they are to inclose. The edges of the bars next the pattern are chamfered (Fig. 251). They may be placed from five to seven or eight inches apart in the box, contingent upon size and circumstances. In common with the box sides, let them have plenty of taper—from $\frac{1}{8}$ inch. to $\frac{1}{4}$ inch.

Fig. 251.

Strong lugs are placed at intervals on the box sides (Fig. 252, *a*, *a*), to carry the pins which connect the parts together. During casting the latter are kept close, either by weights or cottars; in the latter case cottar-ways are cut through the pins. Swell pieces (Fig. 252, *b*, *b*) are put on the ends to impart strength and to give extra thickness for the swivels, *c*, *c*, to carry which pocket prints are fastened on the swells. Flanges are often cast round the top and bottom edges, *d*, both for convenience of turning the box over and for the attachment of flat stay plates to support the sand in deep vertical casts, such as cylinders and plungers. For lowering boxes into the foundry pit by the crane, or for rolling over, handles, *e*, *e*, are often cast on the sides, to carry which pocket prints will be needed.



Figs. 252.

In these rough foundry patterns varnish is not used; often they are left rough from the plane. Sometimes, however, in these, as in other heavy patterns, the deeper faces are seared with a hot iron, sufficiently hot to scorch, smoothed over the surface.

Turn-over boards are also called bottom boards and joint boards. Their purpose is to assist the moulder either by economising his time, which would otherwise be wasted in levelling or jointing, or by rendering temporary support to a pattern which, but for that aid, would yield excessively to the rammer. In the former case the board has a plain surface; in the latter it follows the outline of the pattern, whatever that may chance to be. When the board is plain and the pattern in halves, the bottom half of the moulding box is laid upon the joint board, inclosing one half the pattern, which

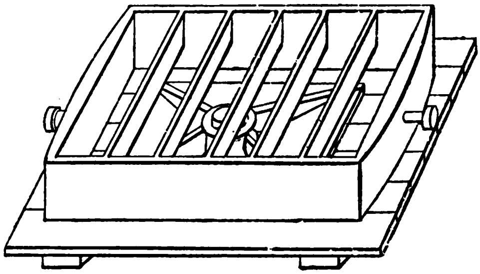


Fig. 253.

also has its joint upon the joint board, and is there rammed up (Fig. 253). Both joint and pattern are therefore true without the trouble of levelling with winding strips. The box then removed from the board and turned joint upwards,

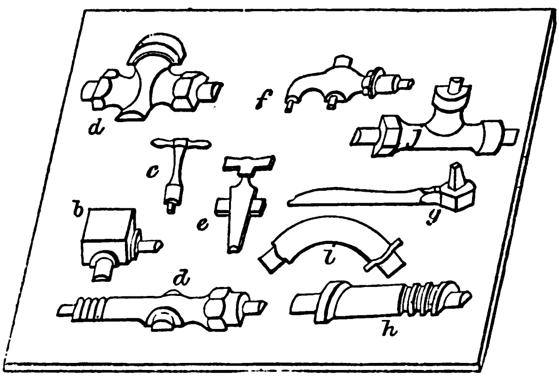


Fig. 254

receives its top part and the other portion of the pattern for the completion of the ramming up.

A board of this kind should be made stout, of from 1½ inch to 3 inch stuff, according to size of work. Pitch-pine or red deal are better than yellow pine, because harder. The pieces of which it is composed should be narrow and open-jointed, to allow for the swelling and expansion in width which will take place in damp sand. They will be held in place with stout battens screwed underneath, 4 inches to 6 inches deep, by 2 inches or 3 inches thick.

But many small patterns are made without joints, particularly in brassfinisher's work—as cocks, valves, plugs, and so forth. The mould, however, has to be jointed, though the patterns are not, and, since they are made in quantity, they are rammed up on a turn-over board—a board which is *recessed out* to receive a number of such patterns at once. The patterns fit loosely into their recesses, and their centre lines correspond with the face of the board. The ramming up process is the same as that described in the previous instance. Fig. 254 shows such a board, having some patterns, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *in situ*, and some spaces, *i* and *j*, from which the patterns have been removed.

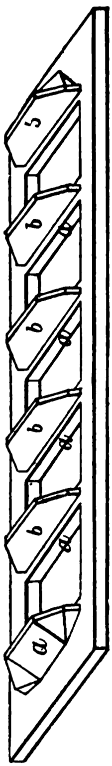


Fig. 255.

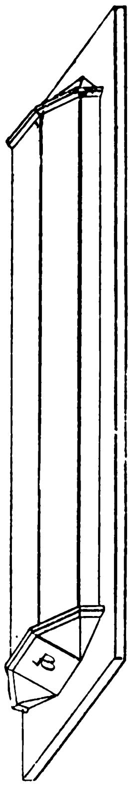


Fig. 256.

The turn-over board for the pattern of a gutter casting (Fig. 255) will afford an excellent illustration of that type which is framed to give temporary support to patterns too slight in themselves to retain their proper shape in the sand.

The bottom board in this case answers three useful purposes. Gutter castings are very thin, not more than $\frac{1}{4}$ inch, oftener $\frac{3}{16}$ inch, so we stay our otherwise weak pattern upon its blocking. Then, in consequence of their shape, they invariably curve in cooling, and we counteract this by imparting the amount which experience tells us they will curve to the bottom board, but of course in the reverse way. Also we make the moulder's joint (Figs. 255, 256, *a*, *a*,) at the gutter ends, and so save him the trouble of sleeking it every time he rams up the pattern. But for these precautions, the gutter ends, flanges, or sockets and spigots, as the case may be, would be awry, and not match one another; and the castings would be hollow on the back, so that the water would always find a low place to lie in instead of running right away. In a gutter of the annexed section the open side must be made *hollow* in the pattern to bring the casting straight. In a 6-feet or 7-feet length the amount of hollow will range between ¼ inch and ⅜ inch, variable according to its depth; so we round the face of the bottom board by that amount, and the sketch (Fig. 255) shows how it is best made.

First there is a stout frame of, say, 3-inch stuff, mortised and tenoned, or else jointed with half lap joints. It must be both wide and long enough to leave a margin of sand beyond the sides and ends of the gutter, and to take in the moulding-box lugs besides, for the reception of whose pins holes are bored with a centre-bit. Blocks of stout wood are screwed on the cross ribs of the frame (Fig. 255, *b*, *b*), at intervals of 10 inches or 1 foot—of exactly the same shape as the inner cross section of the gutter. These being parallel and fastened on a curved surface, will partake of the gutter curve. At this stage the pattern is made, the thin strips which form its sides and bottom being glued edge to edge and bradded while in place—flanges and sockets and spigots being added at discretion (Fig 256). Then, for the convenience of the moulder, we screw the chamfered block at each end of the board, *a*, *a*, to form his joint. All is ready now; the pattern being laid upon the board, and the bottom box dropped over, the sand is rammed around, and forms the reverse of the outside of the gutter, with its terminal chamfered joints, and its longitudinal curved side ones also. The box with the gutter *in situ* is then lifted and turned over, the top part put on and rammed up. The box parts are afterwards separated and the pattern drawn. Thus both rapidity and accuracy are secured, which would have been impossible of attainment with an unsupported wood pattern. We may note that the patterns of gutters are often made in metal.

Another modification of the joint board is seen in plate moulding. But here a still further economy is obtained, since the founder has not even to turn his mould over. The boxes are not, in fact, brought together until the mould is finished; neither are the runners cut by hand, since they form part of the pattern in the plates. Figs. 257 and 258 illustrate plates with common lift valves, clack-box covers, and hand-wheels upon them.

In this case the top and bottom of mould are rammed each upon its separate plate, and when brought together, correspond exactly. Necessarily, in order to attain this result, the pattern-maker must work with extreme accuracy, else the joints of the castings will overlap one another.

Fig. 257 is the plate which gives the bottom of the mould, and upon this the deeper portions of the patterns are fastened if comparatively shallow, dowelled if deep, and the runners to each radiate from the central feeder or gate. The strips

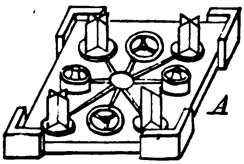


Fig. 257.

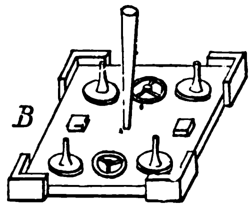


Fig. 258.

screwed at the corners of the plate are there for the purpose of clipping the moulding box without allowing any slop movement sideways.

The next plate, Fig. 258, has upon it the top portions of the patterns, corresponding in position with those upon the lower plate, a central stud-hole being bored to receive the runner pin. It also has clips for the maintenance of the box in position.

The two corresponding halves of a well-fitting moulding box are rammed, one on plate A, the other on plate B. Being then put together by their pins, they form the complete mould ready for the pouring of the metal. Sometimes, where the quantity of castings will cover expense, a machine is fitted up to still further save time, the wooden boards being replaced by planed metal tables, metal patterns, &c.

The core and drawback plates which moulders use do not require patterns, but are formed in the sand from sweeps or strips, which the pattern-maker supplies. The jaggers are stamped in the mould. Grids of various sizes are made from one stock pattern grid, stopped off as required. Large core-bars are made from pipe patterns, and the air-holes are either cast or drilled in.

CHAPTER XXVII.

HEAVY MACHINE WORK.

Variety of Types.—Hollow Framing.—Planing Machine Bed.—Loose Strips.—Cored Portions.—Taper.—Standard of Machine.—Chaplet Blocks for Cores.—Travelling Table.—Open Joints.—Wall Drilling Machine.—Radial Drilling Machine.—Boxing up.—Core-box.

THIS includes types of so many different kinds that the barest description of them would be incompatible with the general scope of this book. Lathes, drilling, shaping, planing, boring, slotting machines, steam hammers, punching, shearing, riveting machines—all of them engineers' tools. The subject is both varied and attractive in the highest degree. But we shall find it more to our advantage to take two or three of the principal and more typical castings, and to thoroughly understand the construction of their patterns, than to run over the whole field in a cursory and superficial manner.

One thing strikes the most casual observer who walks through an engineer's shop—the massive appearance of the framework of the machines. Everything has a solid-looking exterior, contrasting very markedly with the old skeleton-like types that linger yet in some of the older firms. But these ponderous-looking castings are really most economical of metal, since they are hollow, the form which best combines lightness with strength, their thicknesses ranging from about $\frac{3}{4}$ inch to 1 inch or $1\frac{1}{4}$ inch.

The lathe furnishes the oldest type of the engineer's tools, and contains in itself the essential principles upon which many others very diverse in appearance are constructed. Without the automatic slide, not only would our lathes have remained in the same rude condition in which they were found by Henry Maudsley, but those other machines whose value depends on tne parallelism of their faces would have remained in the limbo of oblivion. Postponing, however, the discussion of lathe matters to the next chapter, we pass at once to the machine which comes next after it in importance—the planing machine.

Looking at its bed (Figs. 259, 260) we observe the V-shaped grooves for the sliding table, running its whole length, and

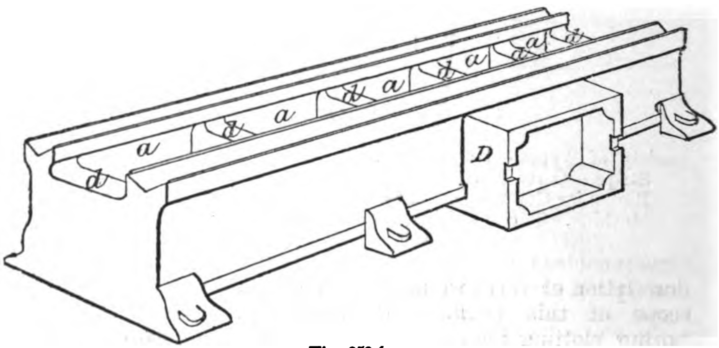
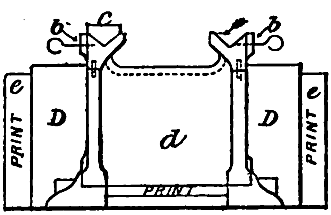


Fig. 259.

projecting several inches within the sides. They are planed truly linear and smooth; hence they must mould downwards. Moulding thus, it is necessary that they should be left loose, and the best way of jointing is to dowel as shown (Fig. 260). After the main pattern is removed, and the middle sand cores (*a*, *a*, *a*, *a*, *a*) are lifted out, these strips could be drawn upwards but for one obstacle—the overlapping portions, *b*, *b*, projecting beyond the outer edges. These, therefore, should be wired loosely



Section of Bed.

Fig. 260.

on the already dowelled pieces, to come in after their removal. Or, if the hollow on *b* is not undercut, the V strips entire may be drawn in after the removal of the bed by a sidelong motion in the direction of the arrow—that is, of the outer V face. Sometimes, however, the V's are taken out with cores, in which case the print c (left-hand side) would prevent the removal sideways, and the outer piece must be left loose.

The cross-bars, *d*, are cored out (Fig. 261) with the view of lightening them, and thin prints for that purpose are fastened on the back and lifted in the top. The outside faces of these cross-bars, together with the sides of the bed, should have at least ⅛ inch of taper, or more if the bed be large. The

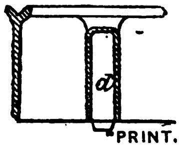


Fig. 261.

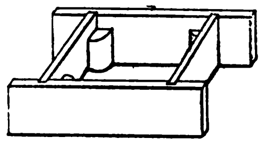


Fig. 262.

blocks, D, D, upon the sides (Figs. 259, 260) are for the attachment of the upright standards, and are cored out with prints, *e*, *e*, screwed against their sides. The bosses in the corners are for the purpose of receiving the bolts which retain the two parts together, and are placed in the core-box (Fig. 262) at a distance below its edge equal to the thickness of the prints, *e*, *e*. These blocks and the cross-bars are "boxed up" (Chap. XI., p. 74) and attached to the sides with screws. The feet are worked out of solid stuff and screwed on permanently, as also is the fillet or moulding running round the bottom edge. The bosses for carrying the driving and quick-return shafts, &c. (not shown), must all be wired on loosely. Such a bed should have lifting straps down its sides (Chap. XXII., p. 159).

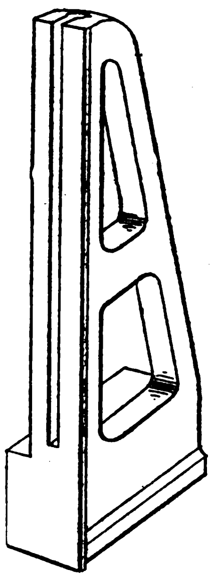


Fig. 263.

It may be taken as a rule in ribbed or flanged castings that plenty of taper should be given to those faces which are not working parts. Strength is not sacrificed—the average thickness being maintained—and the risk of the breaking up and damaging of the mould is vastly diminished. Also, *round* all parts that can be rounded—the edges of these cross-bars for instance—a rounding edge having a more graceful appearance than one quite angular.

The standard (Fig. 263) is either "boxed up" or made of solid bars mortised together. It moulds upon its side with the face which bolts to the bed downwards, and a print is screwed on this joint face to carry a portion of the lightening core. One pattern will suffice for both standards, by reversing the parts from one hand to the other. The core will cut through on the bottom—the top—the joint face, and on the slide, but no prints will be required save that one on the joint face just mentioned, which bolts against the machine bed. Elsewhere the core will be supported and steadied by chaplets. In nearly all large hollow machine castings chaplets furnish the chief support to the cores, prints being available to but a limited extent. In their rudest form they are simply thin plates of hoop iron, into which a bit of wrought bar of the necessary length is riveted, the opposite end of the bar being steadied against a bar of the box, or a cubical wooden chaplet block embedded in the sand (Fig. 264). These chaplets, arranged at the discretion of the moulder around the otherwise unstayed portions of a core, effectually prevent the liquid pressure of the metal from thrusting the core against the side of the mould.

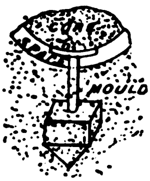


Fig. 264.

The core-box for the main core of the standard will be made as shown in Fig. 265. It is very similar in appearance to a pattern partly boxed up. The strips which form the

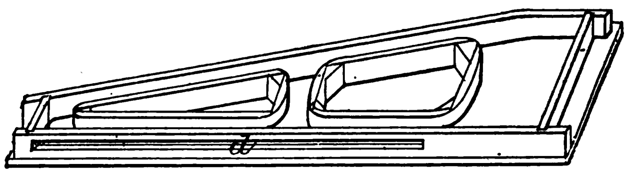


Fig. 265.

bottom of the box may be battened together, and should be at least 1½ inch thick. The sides will be abutted together first, and then after being sustained with stout blocks glued and screwed into their angles the radii will be worked, the whole of this portion of the box being kept in position on the bottom board with dowels. The groove for the nut for the vertical screw is cut through the side of the box at *d*. This core does not include that which cuts through the joint face block. This will be made in a distinct box, similar to Fig. 262, and laid in the mould first, the main core being subsequently laid upon it.

Looking at the travelling table (Fig. 266) we see a recessed portion at each end dropping a little below the T-headed bolt recesses. We shall take advantage of this fact, and make

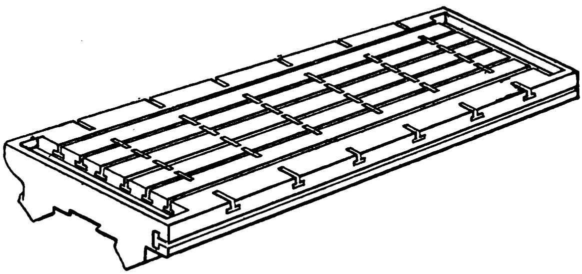


Fig. 266.

our table in such a way that it cannot get out of truth. The plate will be formed of two thicknesses of stuff, the lowermost thickness being equal to the plate at its thinnest (Fig. 267, *a*), the uppermost equal to the thicker portion, *b*. The thinner

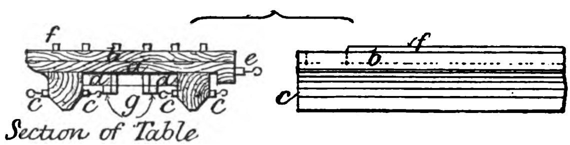


Fig. 267.

pieces will be equal to the table in length, and sufficient in quantity to make up the width. We shall not glue these pieces edge to edge, but joint with open joints; that is, leave about $\frac{1}{8}$ inch between each strip of timber. If we were to glue our pieces together in a pattern so wide, a few hours of exposure in the damp sand of the foundry would expand the wood sideways, and either make the pattern too wide or else curve it. The open joints allow of localised extension, and so the bounding edges of the pattern remain unaltered. On the lower longitudinal pieces thus jointed, screw in a transverse direction sufficient stuff to form the thicker portion, *b*, also with open joints. We shall thus have a rigid table that will not go out of truth either by the action of damp or heat.

Upon this we put the remainder of the work, very simple indeed. The long V-shaped sliders have narrow planing strips wired on their sides (Fig. 267, *c*, *c*). Strengthening ribs are often placed crosswise underneath on heavy tables, *d, d*. Sometimes in the larger machines the sliders are lightened out at intervals with rectangular holes, in which case pocket prints on both sides will be used. A T-headed groove is run along one edge (frequently along the bottom) to receive the tappets. The core for this will be fixed by a print wired on *e*. The prints on the face of the table, *f* (Fig. 267), for the T-headed bolts, need only be shallow, $\frac{1}{2}$ inch or $\frac{3}{4}$ inch deep, and the cores will be made in short lengths, say 18 inches or 2 feet, placed end to end, as also will be those for the tappet groove. It will aid the moulder if all the work on the under side, sliders, and ribs is left dowelled, to come away with the top sand, rather than that the top sand should be dragged away from them. The lugs, *g, g*, are for attaching the travelling rack to.

A plain wall drilling machine is made almost precisely like the casting. The plate or web is not cut from the solid, but halved together with half lap joints, and the ribs, having about $\frac{1}{8}$ inch of taper on their inner faces, are screwed fast upon both sides of the web. The bosses for spindles are cored out, if cored at all, with pocket prints. But the case is not so simple when we have to do with more massive frames, or with radial machines. A heavy, solid-looking frame is boxed up and cored out like the planing machine standard just described, but the core-box is often more difficult to make. Especially is this the case with large curved brackets, having their curves irregular and in different planes. Careful measurements taken from plan and elevation views are then essential. Without such care, the thickness of metal in the casting will vary considerably, and after the pattern-maker has done his best the moulder will often detect variations in thickness by means of his clay templets.

If to the remarks already made we add a description of a radial drilling machine, enough will have been said to enable a reader of ordinary intelligence to understand the construction of any of the common machine castings of this type.

Looking at it (Figs. 268, 270), we see that the top and bottom portions are projected upwards and downwards to form bearings for swivel movements; the back is hollowed out deeply to receive the vertical spindle and gearing, and the Vee'd strips are cast on the horizontal arm which stands out at right-angles with the vertical axis of the machine. We can only mould it in one way—on its side, with the Vee'd face downwards. Evidently, then, the hollow back must be taken out with a core, which core must be supported by a sufficiency of print. Then there is a boss for horizontal telescopic spindle, with abutting ribs, and between this boss and the radial arm there is an intervening space, *d*, to be taken out.

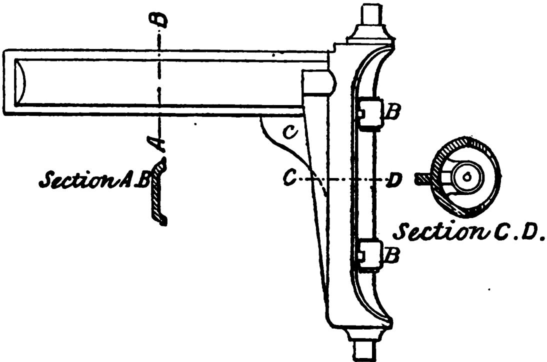


Fig. 268.

We shall decide to joint our pattern along the longitudinal centre—that is, through the centre of the boss and rib. Being large also, we will box or lag up each half in preference to using solid timber. It will be lighter and less liable to get

Fig. 269.

out of truth. Make four or five blocks (Fig. 269, which represents one half the pattern, looking against its joint, and a section also), *a*, *a*, *a*, *a*, dowelled together, and glue and screw lagging strips, *b*, *b*, *b*, *b*, across these, to include both the

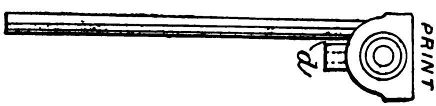
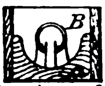


Fig. 270.

curved portion of the pattern and also its print, bringing the print edge level with the termination of the pattern side (Fig. 270). The rounding ends and the swivel projections will be prepared as separate pieces, and screwed against the ends of the lagging. The radial arm will be a plain piece of wood to which the Vee's will be screwed fast. It will be fitted against the rounding body at its due distance from the boss centre, and the bracket, *c*, attached to it. The spindle boss and its rib will be made in halves and screwed in place. The pattern itself is now complete, but the space, *d*, between the boss and arm is rather awkward. If but one or two castings are required let it remain so, and the moulder will use a draw-back; but if for standard use put in a print, and make a core-box for the recess.

Fig. 271 is a section of the core-box, which takes out the back of the vertical portion. It is made, as is usual with rectangular boxes, with two sides and two ends grooved in. Into this a block of wood worked to the shape of the inside of the vertical pillar is dropped, *a*, the ends of which are curved just as the edges of the casting are curved. The lugs for carrying the spindle are shown at B, each having a pocket print on opposite sides, and a loose boss wired on.



Section of Core Box

Fig. 271.

There is much similarity in these machine castings. When we are conversant with one type of frame, and the method of making and moulding it, we see, almost as if by intuition, how to make one of a different class, yet to which the same methods will apply. Almost all will be resolved into two kinds, the ribbed and the solid. Of the one the planing machine bed may be taken as a type; of the other its standard and the radial drill furnish illustrations. Large slotting, shaping, punching, shearing machines, and so forth, are all boxed up and cored out; lathe beds, many drilling and boring machines, have a ribbed framework. The patterns are made strong and substantial, and instead of being varnished are usually painted.

CHAPTER XXVIII.

LATHE MATTERS.

Lathe Beds.—Advantages of Coring Beds.—Boxing up.—Attachments. —Core-boxes.—Saddle for Slide Rest.—Transverse Slide.—Standard. —Headstocks.

There are two ways of making lathe beds: one is to construct the pattern like the casting, leaving certain parts loose, and giving due taper both to external and internal portions; the other is to box up a pattern, and to core out the internal portions. Of these two methods I am going to describe the latter, because with a cored-out pattern there is less chance of an untrue casting being produced, such a pattern being less liable to become rammed winding, or otherwise out of truth in the sand. If I were going to make a small bed such as this is for myself, knowing the moulder who would mould it, and that I could check it with straightedge and strips in the sand, I would not bother with cores; but if cast in a strange foundry, perhaps by men unaccustomed to this class of work, I would not run the risk of getting a crooked bed by constructing a pattern of so slight proportions. To such as wish, however, to mould in greensand simply, the view of Fig. 272 is self-explanatory. A pattern made thus (one only of two or three methods) will be made correctly for moulding, remembering of course that the top of the bed is the bottom in the mould.

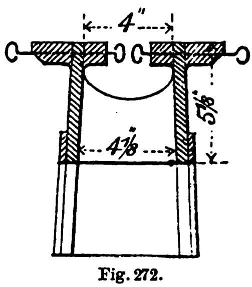
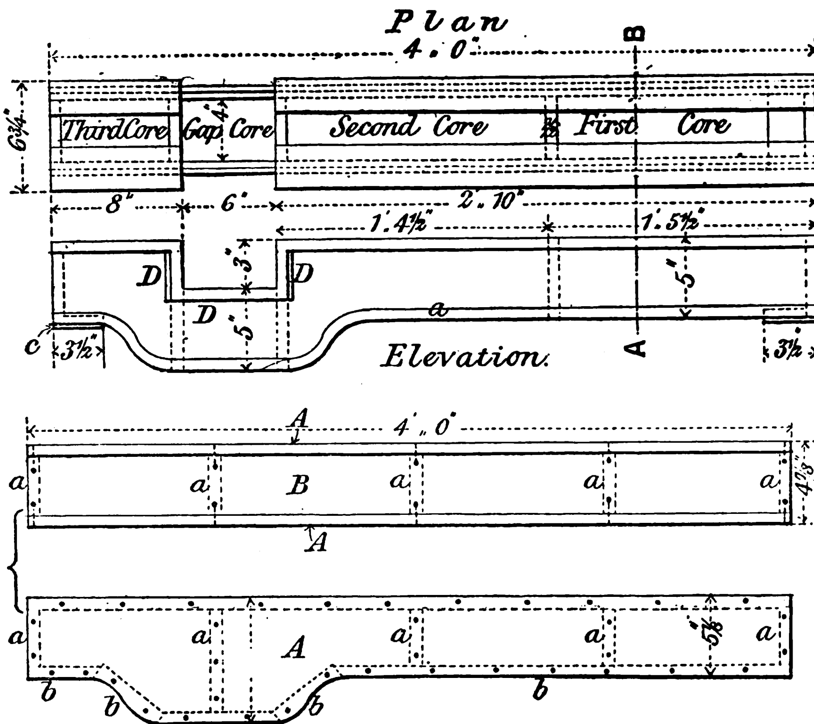


Fig. 272.

Fig. 273 shows a fairly proportioned bed, dimensioned for the sake of clearness of illustration. It might perhaps be lengthened six or twelve inches with advantage, dependent upon the class of work for which it is to be adopted.



Figs. 273 and 274.

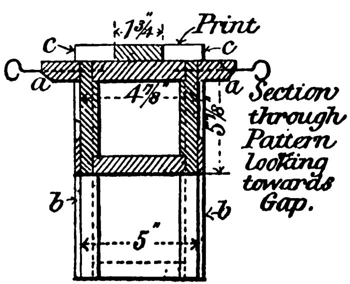


Fig. 275.

"Box up" the main body of the pattern (Fig. 274). Procure some inch board, out of which cut two sides (Fig. 274, A, A, A) slightly larger than the outline of the bed. Rebate them $\frac{1}{8}$ inch deep to the width of an inch all round, and also across where the ribs or stays, *a, a, a, a, a,* are to come. Then prepare one piece for the top (B) 4 feet $0\frac{1}{8}$ inch long by about $3\frac{3}{8}$ inches wide. We say "about," because the stuff in the sides may be full or bare in thickness, and we want the bed to measure 5 inches over the sides when roughly boxed up, the finished width being $4\frac{7}{8}$ inches. Prepare pieces likewise for the bottom, *b, b, b, b, b,* of the same width as the last, also the cross ribs, *a, a, a, a, a,* of the same width too. Nail or screw all together. Plane up the sides to $4\frac{7}{8}$ inches wide at the bottom (bottom from the moulder's point of view, really the top face of the lathe bed) by 5 inches bare at the top. Plane over the face straight and square with the vertical centre of the bed—*i.e.* so that the taper in the sides is equal relatively to the top; shape the blocks that form the swell round the gap, and plane $\frac{1}{16}$th taper at the ends of the bed.

The main body is now ready to receive its equipments. Make a print 4 feet by $1\frac{3}{4}$ inches by $\frac{1}{2}$ inch and nail it upon the centre of the face (Fig. 275). (In reference to the apparent discrepancy between the width of the print here given and the width of the groove in Fig. 273, as also to other instances of the same kind, as $5\frac{1}{8}$ inches depth of bed in Fig. 275 against 5 inches in Fig. 273, let me remark that these are the usual "planing" allowances). Extend the width of this print *just over the intended gap* to $4\frac{7}{8}$ inches (Fig. 276, Fig. 275, *c, c*),

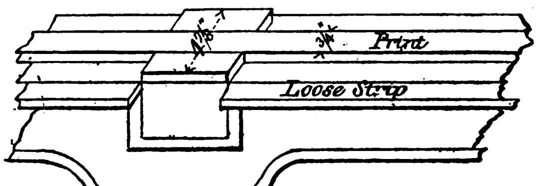
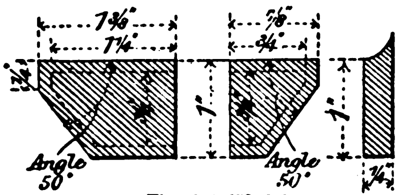


Fig. 276.

the reason of which provision we shall see by-and-by. Prepare the outer V-shaped strips to the sections (Figs. 277, 278), and wire on in place (Fig. 275, *a, a*). The outer lines in Figs. 277, 278 are the *pattern* lines, the inner ones represent the *planed* sizes. Make the fillet to section (Fig. 279), planing the straight portions, and cutting the curved parts round the gap with gouge and chisel, and nail or screw in place (Fig. 273, *a*, *a*; Fig. 275, *b*, *b*). The strips, D, D, D, round the gap must, however, be wired on. The two facings for the standards, 5½ inches by 3½ inches by ¼ inch (Fig. 273, *c*, *c*), complete the pattern.



Figs. 277, 278, 279.

For the first core (Fig. 273, plan), frame up a box 1 foot 5½ inches by 4 inches by 5⅝ inches (Fig. 280). This is long enough to include the first and second ribs, and deep enough to include the print. Plane two strips 1 foot 5½ inches by 1⅝ inch by 1⅛ inches, equalling respectively length of box, depth of inner strip and print, and width of inner strip with planing allowance, and screw them against the sides of this box flush with its top edge (Fig. 280, A, A). Prepare two cross-bars ½ inch thick to the shape and dimensions indicated in Fig. 281, which represents a section of the box, looking towards the end, and screw in place (Fig. 280, B, B). Prepare a piece 4 inches by 3 inches by ¾ inch, and fasten at one end for the standard facing (Fig. 280, C).

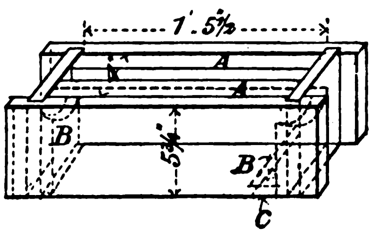


Fig. 280.

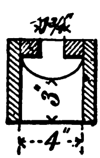


Fig. 281.

The next box is framed to 1 foot 4½ inches by 4 inches by 5⅝ inches, and one end is made to follow the outline of the pattern (Fig. 282). In the end next the gap, a cross-bar similar to the others, but 3 inches deeper, is fixed (B). The guide strips, A, A, for the poppet, as in the last box, will be required. The box for the third core (Fig. 283) will be 8 inches by 4 by 5⅝, having strips, A, A, cross-bars, B, B, and facing, C, for standard; or the second box may be utilised after its core is made by screwing a cross-bar in, 8 inches from the end next the gap, and putting in the necessary parts.

The gap box (Fig. 284) is framed to 6 inches by 4⅞ inches by 8⅝ inches. This, it will be seen, corresponds with the

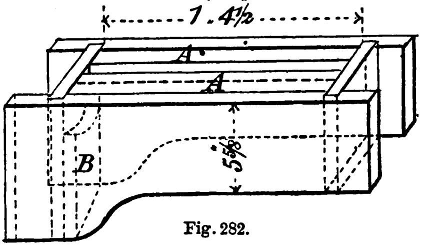


Fig. 282.

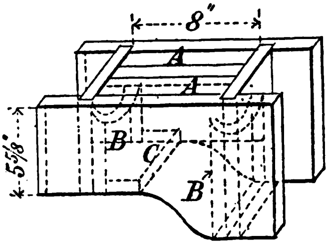


Fig. 283.

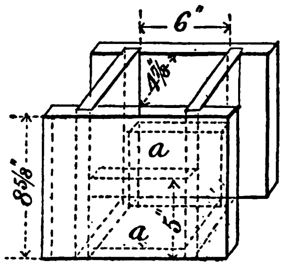


Fig. 284.

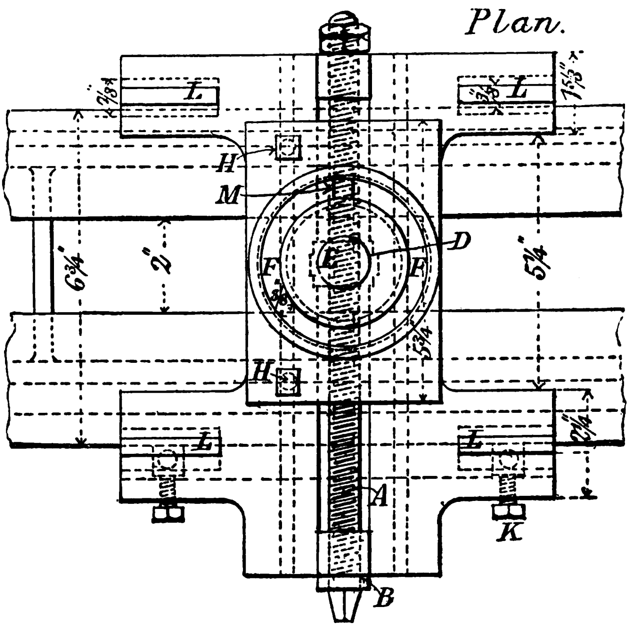
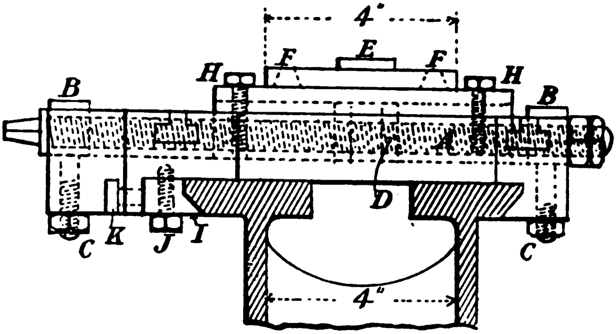


Fig. 285.

print in Fig. 276. Against the sides of box screw two blocks 6 inches by 5 inches by $\frac{7}{16}$ inch (Fig. 284, *a*, *a*), to form the metal at the sides of the bed below the gap.

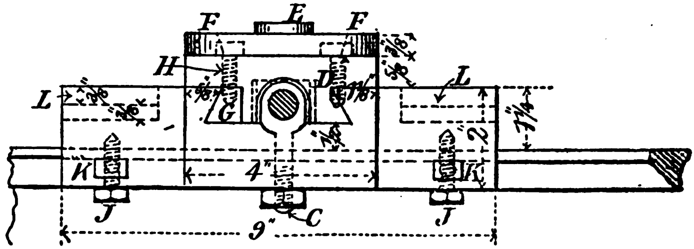
Fig. 285 shows the saddle and transverse slide suitable for the bed we have just described in plan, Fig. 286 gives a side



END VIEW.

Fig. 286.

view, Fig. 287 one in front. A is the screw; B, B are the nuts attached to the saddle by the screws C, C; D the nut held in



FRONT VIEW.

Fig. 287.

the transverse slide, through the medium of which the motion of the screw is communicated to the slide; E the stud for the longitudinal slide; F, F a turned bevelled groove to receive the tightening nuts for the upper slide; G loose strip for transverse slide, tightened up by screws H, H; I is the loose strip for the saddle, fastened by screws J, J, and *set* by screws

K, K; L, L are slots for T-headed bolts, for convenience of holding work to be bored. The bosses for the rack pinion movement are omitted to avoid crowding.

Taking the pattern of the saddle first (Fig. 288), make the main plate 2 inches thick, to dimensions given, framing the

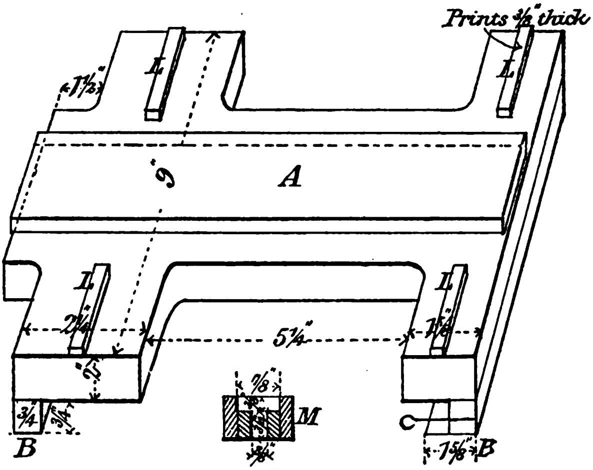


Fig. 288.

parts together either with half-lap joints or by mortises and tenons; nail on a print, A, ½ inch thick, to take out the recesses for the transverse slide; screw on the strips B, B which embrace the lathe-bed, wiring on the Vee, which is cast in a piece with the saddle. Fig. 289 shows a section of the core-box for A, looking towards one end. By means of the curve, *a*, on the end crossbars of the box, the core is strickled to a corresponding shape

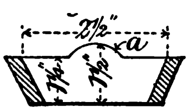


Fig. 289.

Fig. 290.

for the purpose of taking out the recess underneath the traversing screw. The prints, L, L, L, L, and their core-box, M, shown in section, Fig. 288, are for the T-headed slots, shown in the three views of the rest. Fig. 290 is a half-size section of the loose Vee strip, I, in Fig. 286, giving planing allowance.

Fig. 291 shows the pattern of the transverse slide, top and bottom faces respectively, and Fig. 294 in end view. The plate A is $5\frac{3}{4}$ inches by 4 inches by $\frac{3}{4}$ inch (finished to $\frac{5}{8}$ inch). Upon this the circular face, with its print for the bolt recess, B, Fig. 292 in section, is fastened. Fig. 293 shows the core-box for this recess, in section and plan. A is a bottom board upon which a

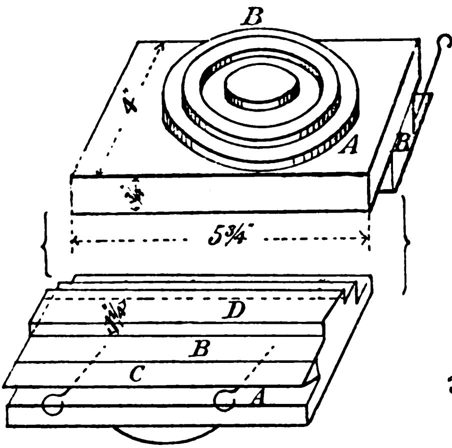


Fig. 291.

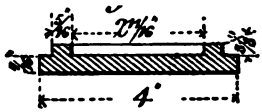


Fig. 292.

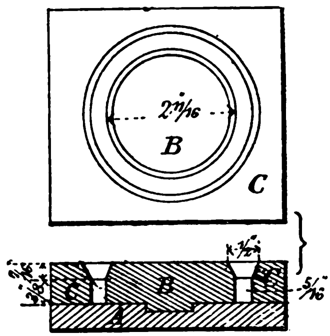


Fig. 293.

centre-piece, B, is studded, and a ring piece, C, dowelled; the unshaded portion being the core space. Note that the width of core is given as $\frac{5}{16}$ inch against $\frac{3}{8}$ inch width of groove on top of Fig. 285. This allows of the barest possible amount of skimming up in the lathe, the core being too small to permit of much turning allowance, neither is much necessary if the box be made truly.

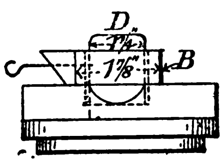


Fig. 294.

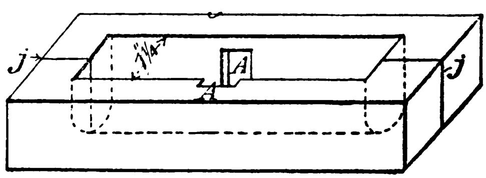


Fig. 295.

A slot will have to be cut in the casting, shown at M in Fig. 285, through which to thrust the tightening bolts into place.

For the under face of the traversing slide prepare a piece of stuff 5¾ inches by 1⅞ inch by ¾ inch, and fasten on in the centre of the plate already prepared (Figs. 291, 294, B); on this wire the loose strip, C, and nail the print, D. Make core-box (Fig. 295) jointed longitudinally, *j*, *j*, and dowelled and recessed at sides, A, A, to receive the brass nut (Figs. 285, 286, D, and Fig. 296).

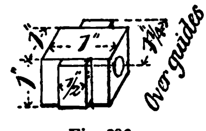


Fig. 296.

The standard (Fig. 297) is suitably designed for the bed which we have described. The frame will be made with

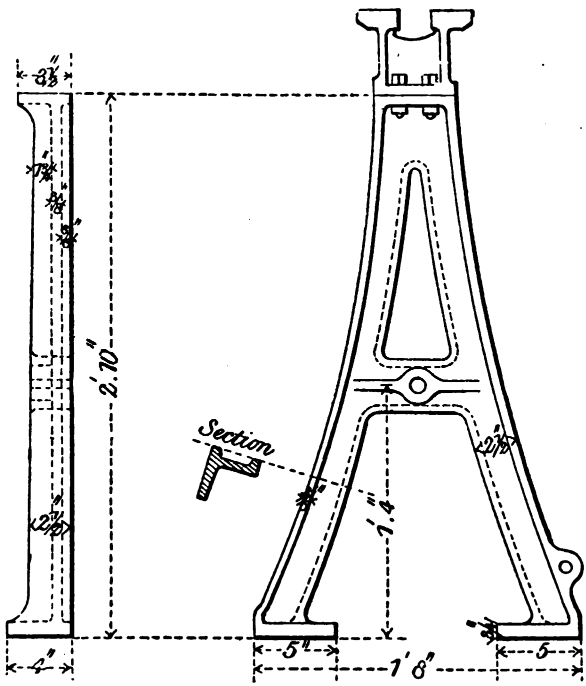


Fig. 297.

half-lap joints, and the ribs screwed upon it with $\frac{1}{16}$ inch of taper on their inner faces. The ⅝ inch ribs on the outer face simply relieve the otherwise heavy appearance of the casting.

Headstocks and poppets are jointed either longitudinally in their vertical plane, thus moulding upon their sides, or they are made to mould top side down, the barrel of the poppet being loose in that case, and the overhanging portions also of the headstock being left loose; or where the overhang is considerable, as in arms for back gear, the sides are taken away on drawbacks.

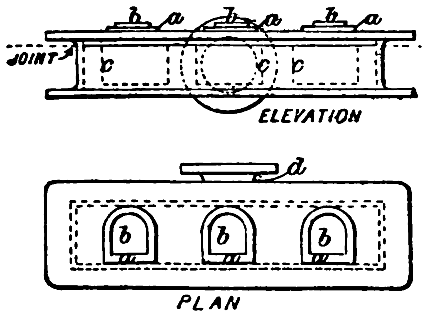
CHAPTER XXIX.

PUMPS, COCKS, AND VALVES.

Three throw Pumps.—Suction-box.—Delivery-box.—Jointing.—Barrel. —Its Core.—Bucket.—Air-vessel.—Strainer-pipes.—Their Cores.— Sluice-cocks.—How Moulded.—Gunmetal Faces Cast and Turned in. —Plug.—Nut.—Force-pumps and Core-boxes.—Small Brass Work. —Globe-valve.—Methods of making Cores.

THE varied character of pump work forbids all except a brief description of the commoner forms. The essential parts are barrels, plungers or pistons, suction and delivery boxes, more or less elaborate in detail, and air-vessels. Single-barrel, two-throw, three-throw, hand and steam, single and double-action pumps, vary more in details than in principle or general design, and are not usually very intricate. But almost always the internal portions are cored out, and the core-boxes are generally of the most importance, often involving more work than the patterns themselves, and in certain cases requiring very great care on the part of the pattern-maker.

Let us run through the main patterns for a set of three-throw pumps first of all. The pattern of the suction-box is made as indicated in Fig. 298. One flange at least, sometimes both flanges, are dowelled on to the body, and upon one of these flanges are fastened the facings for the barrels, *a*, *a*, *a*, and the prints, *b*, *b*, *b*, for the holes that flange moulding downwards, or the reverse to the figure, which shows the box as it stands in natural position. In standard patterns it is customary to work the hollows around the flanges, and then the loose flange will be planed thicker by that amount. Sometimes, instead of a mere suction-box, where the valves rest upon the facings, *a*, *a*, *a*, we have a clack-box—that is, a box which either contains the valves on their diaphragms inclined at an angle towards the front, or else on the top of a suction-box cast separately and bolted up from below. Then there is a door-way, dotted at *c*, *c*, *c*, cast in front of each valve aperture, so that any temporary defect in either of the clack-valves may be seen and remedied without removing the barrels or taking the structure all to pieces. Where this is the case these holes will not require to have prints upon the pattern. If



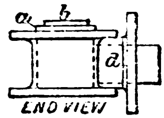


Fig. 298.

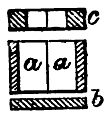


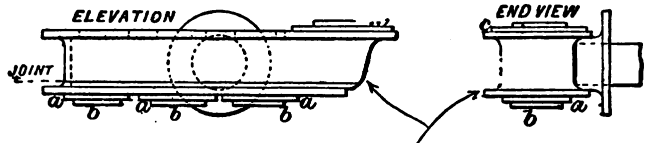
Fig. 299.

there is a branch in the bottom for the suction it will be studded on loosely, and its flange—unjointed—will be slipped loosely over the print. If upon the side, *d*, the branch will be fast, and the flange either slid loosely over, as in the first case, or parted in two, the top half being left loose.

The core-box is usually made in several pieces (Fig. 299). The two blocks, *a*, *a*, dowelled, are cut to form the inside of the shell. If holes are cored for doorways, as supposed above, *c*, *c*, *c*, they are cut in the side of one of the blocks—the thickness of that block being gauged to represent the metal-thickness. A bottom board, *b*, is dowelled on, and a top board also, *c*, the latter in halves, and dowelled, and being equal in thickness to the thickness of the top flange together with its facings and prints. Holes are cut in the latter piece of the same shape and size as the prints.

The delivery-box (Fig. 300) is not very different from the suction. In this, also, one or both flanges will be loose; facings to receive the barrel ends, *a*, *a*, *a*, and prints, *b*, *b*, *b*, for their apertures will be fastened on. There will be a delivery branch somewhere or other, in which the same conditions of moulding will obtain as in the one for the suction-box, and probably a facing, *c*, for the air-vessel. The core-box (Fig. 301) will be constructed similarly, in regard to joints, apertures, and so forth; but the hole for the air-vessel, *a*, will cut through the top piece. The core for the delivery branch will not be made in the main core-box, but as a separate piece, and it will rest in its print and merely abut against the body core.

Jointing the patterns in the way described means using a three-parted box in the foundry, with its two sand joints. But in most cases there is no objection to jointing through the centres of the prints, as indicated by the dotted line, and



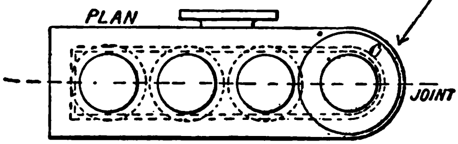


Fig. 300.

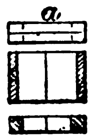


Fig. 301.

making the flanges in the plan (Fig. 300) fast. Then the core-box, also, may be jointed in the same fashion, and its

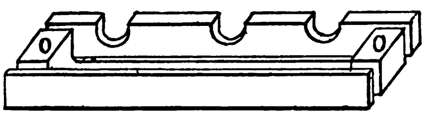


Fig. 302.

sides screwed fast to its body portion. See Fig. 302, which shows the parts of one-half the box made in this fashion, ready to go together.

The barrel (Fig. 303) is turned as a cylinder pattern would be, from solid stuff if of small bore, or lagged up if large—in each case jointed and dowelled, and having prints, *a*, *a*, at the ends. Where an aperture and door are made at the front of the lower end, as is done when the valves rest upon the top of a suction-box, the square portion of the D-shaped block is either worked from the solid or else as a separate piece of wood, and fitted over the main body. The core in that case is struck up by a board and shouldered down as shown at Fig. 304 to receive the D-shaped core, which is threaded on as the square base of our column was threaded on the round shaft core (Chap. XVIII., p. 122). Or the main core is struck to its full diameter, and a saddle piece made from a box of the section of Fig. 305 is fitted against it (Fig. 306).

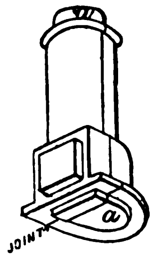


Fig. 303.

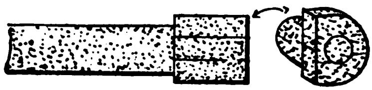


Fig. 304.

Fig. 305.

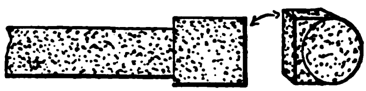


Fig. 306.

The bucket is made as shown in Fig. 307. The piston is turned from the solid, and the arch built up in about three thicknesses of small segments. The arch is fitted to the bucket itself by loose tenons or dowels. The water aperture

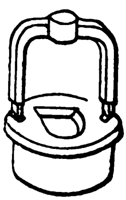


Fig. 307.

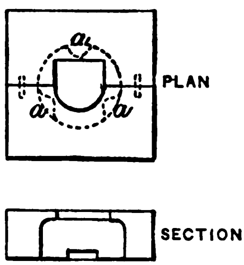


Fig. 308.

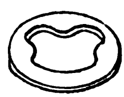


Fig. 309.

is better cored than cut out, the pattern being printed on the bottom, and its core-box (Fig. 308) being made in halves. The three lugs, *a, a, a*, in the bottom of the bucket are for the attachment of the cup-leather guard, shown at Fig. 309, which last is turned and worked from a bit of solid mahogany.

Air-vessels are cored out, the core being struck up. A core-box is only made when several similar castings are required. Frequently for large castings a loam pattern is used for the body itself. The common form is the dome shape shown in Fig. 310, the pattern being jointed to mould sideways, and except at the print end the core rests upon chaplets.

The last of a series of suction-pipes is furnished with a strainer (Fig. 311) at the bottom, to prevent the entrance of any foreign obstructions with the feed-water, which would choke the pump. These pipes are constructed similarly to the air-vessel, but no provision is made in the pattern for the strainer holes. These, numbering several scores in a strainer of moderate size, are made in a peculiar way. The core-box is like Fig 312, its thickness being equal to the thickness of

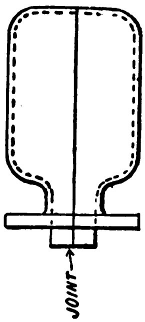


Fig. 310.

Fig. 311.

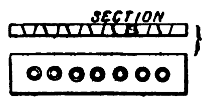


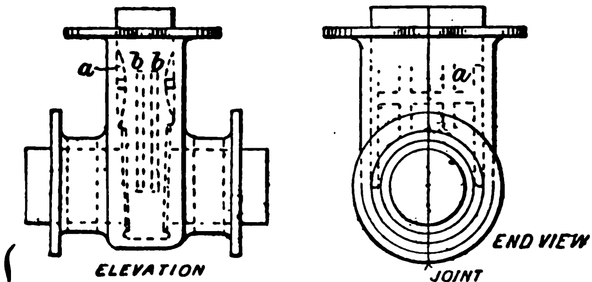
Fig. 312.

Fig. 313.

metal in the strainer bulb, and the holes have a large amount of taper. After being cut with a gouge they are burnt smoothly with a taper iron, its taper corresponding with the taper of the holes. The cores are then rammed up, each with a common cut brad standing point upwards from its centre (Fig. 313). When dried, the cores are stuck around the mould, approximately equidistant, by means of the brad points thrust into the sand. The main core is then laid in, and rests upon these cores, so that chaplets are not requisite.

Sluice-cocks comprise shell, cover, plug, and screw parts. The shell and the plug only need be mentioned. The shell (Fig. 314) may either have flanged or socketed branches—the latter being the more convenient for jointing up. The way of jointing the pattern is not affected, whichever form of branch we make. I have made these with the sockets up and down, and of course left loose (indicated by the dotted lines in the elevation); but this involves putting in the core in three portions—first, that for the bottom socket; secondly, the body; lastly, the top socket—and is therefore not to be recommended. The cheaper way is to joint through the centre of sockets and body as shown in the end view, and so mould the cock edgeways. Then the core is made all in one, as represented in the plan of the open box, and time is saved both in pattern-shop and foundry.

In small cocks the brass facings are cast in a piece with the shells. The facings being cast first in brazing metal with projecting nipples (Fig. 315), are turned bright and laid in the core. The molten iron meeting these, partially fuses the brass and makes a close joint with it. But in larger ones watertight joints cannot be secured by casting in, so they are of necessity turned to fit the turned shell and pulled in close with screw pressure. When they are cast in, the proportion of copper must be large, since common brass or gunmetal would melt at the temperature of molten iron. From 4 inches to 6 inches in diameter is about the limit at which a perfect amalgamation of the metals at the joint can be relied on.



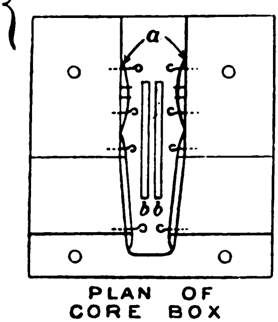


Fig. 314.

Fig. 315.

By making the pattern as we have indicated there are no loose pieces required. In the core-box the only loose pieces are the circular facings which carry the brass rings, and also in large cocks the internal strengthening ribs, *a*. The guide-strips for the plug, *b*, *b*, are fastened in the top and bottom of the halves of the box.

The plug pattern (Fig. 316) is made from the solid, and is turned without, and recessed down on each side to the central web, *a*. On this web boss pieces, *b*, are fitted, to give the metal round the central hole, *c*, which is large enough to allow of clearance for the screw. A block for the nut, *d*, a print, *c*, at the bottom end of the same size as the central hole, and a couple of guide strips, *e*, *e*, skewered on, complete the pattern. The remarks made in reference to the facings in the shell apply to those on the plug. The core-box for the hole has also a recess cut in it similar to the recess cut in the saddle of a lathe to carry the screw-nut.

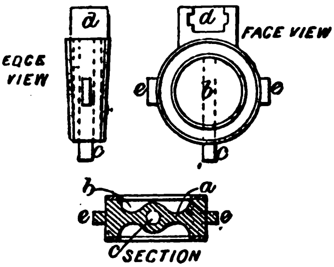


Fig. 316.

The nut (Fig. 317), made of brass, is, instead of being screwed in the lathe, commonly cast upon the thread of a duplicate of the screw itself, three or four such being cast upon one thread at a time. The screw rests in a bed made in the sand by a long pocket print shown in Fig. 317, *a*, *a*, *a*, *a*, which print is of course "stopped over" against the face of each nut.

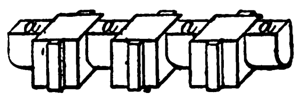


Fig. 317.

Force-pumps, unless when very small, are seldom made from

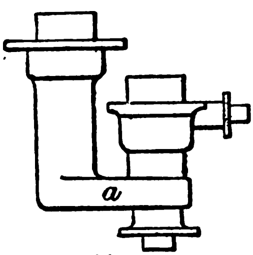


Fig. 318.

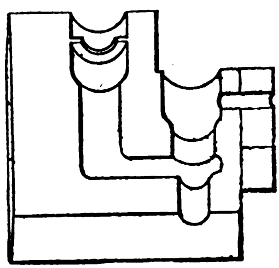


Fig. 319.

solid stuff, because of the liability of the timber to curve and twist. Fig. 318 shows such a pump, in which the turned portions are each made separately, and screwed to the rectangular part, *a*. One half the core-box is shown at Fig. 319, and the stuff of which it is composed is prevented from curving by battens screwed upon the back.

In working a core-box of this kind it is not necessary to make templets for each separate radius. A set-square furnishes a convenient and certain means of checking the accuracy of a semicircle, since, if the edges touch the opposite sides of the diameter while the corner is in contact successively with every intermediate portion, the conditions of a true semicircle are fulfilled (Fig. 320).

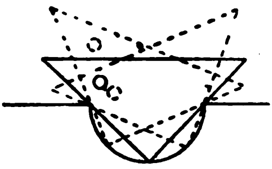


Fig. 320.

In making gland and bib cocks, and similar articles, it is better, unless they are exceptionally large, to cut them out of the solid, and this remark applies to the generality of small brasswork. Of course the parts which are spherical can be turned, even though they occur in different axes, by rechucking, and the portions intermediate worked by gouge and chisel. Moreover, jointing is not commonly resorted to in these patterns. The regular makers seldom joint small work at all, but use bottom boards, and also use metal patterns largely. In places where these things are a speciality, there will be as many as a dozen, or twenty or thirty, of such separate and distinct metal patterns, usually of brass, in a single box. It is marvellous to note the rapidity with which the workmen will lift the patterns out one after another with their fingers, without disturbing or breaking down the sand in the process. But it is essential that the metal patterns be got up well, and that the core-boxes—also of metal—be well jointed.

It is not customary to mark out both halves of a core-box with compasses and square. One-half only is usually marked first and worked. Its face is then either chalked over or smeared with red lead, and the unmarked half pressed closely against it and tapped with a hammer, when the lines of the bounding edges will be transferred by the chalk or red lead to the opposite face. Or where easily got at, a bent scriber is brought into requisition, and being carried round the edges, marks the lines on the opposite half.

The pattern for a common globe-valve (Fig. 321) might be jointed in the plane of the figure (vertical section), and be either worked out of a solid piece, if of small dimensions, or, if large, the globular part would be turned, together with the inlet and outlet ends and their prints—the branch for the screw-gland being turned separately and fitted on. Or the pattern might be jointed at right-angles to the plane of Fig. 321—that is vertically, line A, B—and the branch be moulded downwards; and this I consider the better way, as more convenient for laying in the cores. A small valve has usually nut-shaped hexagonal ends as figured, and is screwed within with gas-taps for the attachment of the piping. But large valves often have flange attachments, both at the ends and on the top,

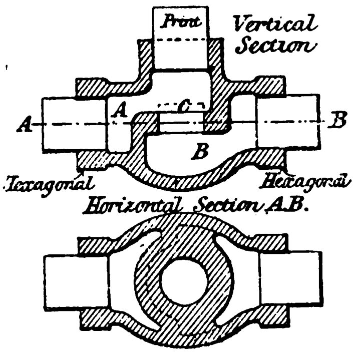


Fig. 321.

and in the latter case the top flange will be left loose if the branch is moulded downwards. The core for a large cock is not made in one, but in two pieces. The cores are

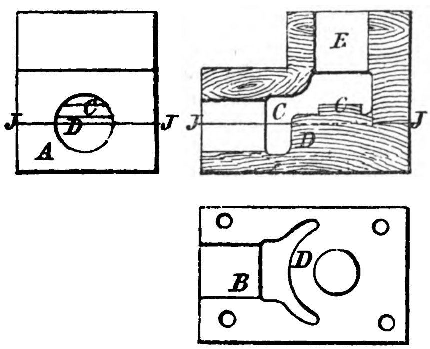


Fig. 322.

made from two separate boxes, and fastened together with claywash before being put into the mould. Looking at Fig. 321, A is one core and B is the other, and they are connected together by the print C, shown dotted in the figure. In setting to work, just dismiss core B from the mind for awhile, and start about making a box for A. Three views of the box are given (Fig. 322), A showing its appearance viewed from its outer end; B, in sectional plan, looking on the face of the core-box joint and downwards; C, a sectional elevation cut longitudinally through the box. Clearly the box parting at the joint, J, allows perfect freedom of delivery for the semicircular portion, D (Fig. 322), and also for the branch part, E, and the print, C will leave a recess in the core, by which core B may be set true. Now make a box for core B, jointed at J, which is

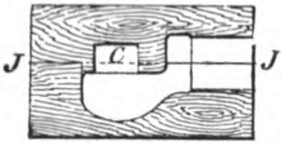


Fig. 323.

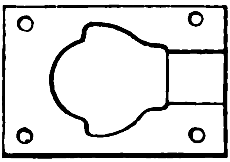


Fig. 324.

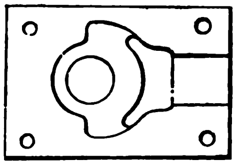


Fig. 325.

(Fig. 323) a longitudinal section. It is shown in plan in the joint, looking downwards, at Fig. 324, also looking upwards in Fig. 325. Evidently now the stud, C, formed in this core will drop into the print in core A, and the two cores together will in section be like Fig. 326, which is exactly what we require. This is the way adopted in making cocks of moderate and large dimensions. In very small cocks, however, say of 1 inch or thereabouts, it is often deemed not worth the while to round the metal outside the valve-seat, and then one core-box suffices. Its plan would be like Fig. 327, and its section, of course, as before; and the joint of the box would show like the vertical section of Fig. 321

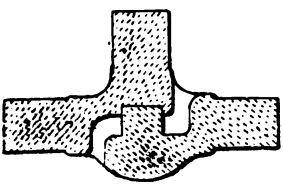


Fig. 326.

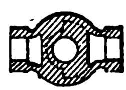


Fig. 327.

CHAPTER XXX.

WATER-WHEELS AND TURBINES.

Water-wheels.—Their Bosses.—For Flat Arms.—For Round Rods.—Shrouding.—Toothed Ring.—Building it up.—Marking out.—The Teeth.—Turbines.—Core-box for Buckets.—Mode of forming the Shrouding.—Core-box for Guide.—The Discs.—Greensand and Loam Moulds.—Turbine Steps.—Lignum Vitæ Strips.—Directions for fitting in.—Governor-ring.

WATER-WHEELS do not come within the range of the pattern-maker's work to the same extent that they formerly did. For, in addition to the fact that the smaller and more economical turbines are largely taking the place of the more cumbrous and extravagant water-wheels, there is also the circumstance that cast iron enters but slightly into their construction. But the fact that there is some cast iron about them, and that the country workman is not unfrequently called upon either to construct or to repair an existing wheel, justifies some slight allusion to the principal parts.

In the first place, then, the structure of the central bosses will vary according as the power is taken from the centre or from the circumference of the wheel. If it be taken from the centre the torsional strain is great, and stout wrought or cast iron arms will be used. Then the boss will have recessed pockets (Fig. 328) to receive the ends of the arms, and the pattern, but for the central print, will be exactly like the casting. The bits, *a*, *a*, *a*, are chipping strips to allow of

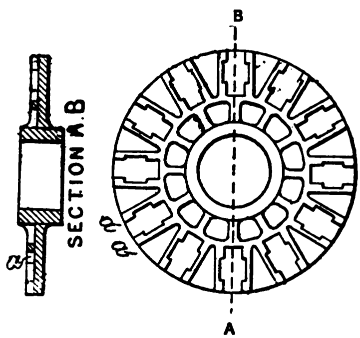


Fig. 328.

accurate fitting of the arms without chipping the edges of the recesses along the entire length. But when the power is taken from the circumference there is very little leverage, and round wrought bars serve both as arms and struts. Then the central bosses take the form of Fig. 329, having arm and strut bosses and cottar ways, *a*, *a*, for the attachment of the rods.

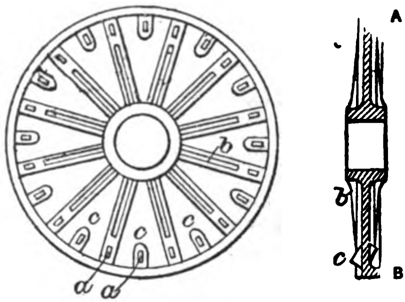
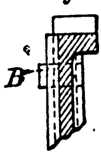


Fig. 329.

In making this pattern a plain plate is turned, of the correct diameter, and with a strengthening rib built up at the circumference. The central bosses being turned and screwed on, the long bosses for the arms are abutted against them. These are turned as indicated in section, Fig. 330. A represents a middle strip planed to the same thickness as the plate itself; B, B represent the actual boss pieces laid against each side of this strip, and held temporarily with screws, as when jointing pattern stuff in halves (p. 160). The three are thus turned together, and the middle piece being removed, the boss pieces are ready to screw in their places and form a circular section with the plate itself. The pieces marked *b*, *b*, Fig. 329, are mere strengthening ribs fastened upon these bosses exactly as required in the casting.

Fig. 330.

On the periphery long pocket prints are fastened, Fig. 331, and on every boss a cottar way print, B. The two prints carry



Enlarged view of pattern at A *on Fig.* 329.

Fig. 331.

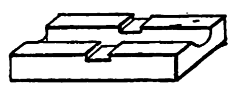
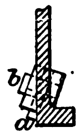


Fig. 332.

the arm core with its cottar ways, made from a box, one-half of which is shown laid open in Fig. 332.

The bosses, *c*, *c*, *c*, *c*, Fig. 329, are for the strutting arms, and these are best turned from the solid, and sawn all alike to a bevel. On these also pocket prints, Fig. 333, *a*, and cottar way prints, *b*, are fastened, for which a short core-box similar to the last will be made.

The shrouding of a wheel (Fig. 334) will also vary with the conditions under which the power is taken off. Round rods will require cottared bosses, and these will be made and cored similarly to those just described on the central boss. Flat arms will require recesses like those on Fig. 334, A.



Enlarged view of pattern at B *on Fig.* 329.

Fig. 333.

When making the shrouding plate it is desirable, where the wheel is large and the number of segment pieces considerable, to make the pattern plate of cast iron, or, better still, of a piece of thin wrought-iron plate, and to screw upon this the curved

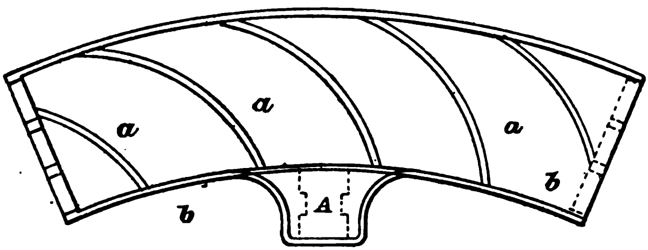


Fig. 334.

flanges, *a*, *a*, either continuous, as shown in the figure, or disjointed, for the attachment of the buckets, and the inner flange, *b*, for the attachment of the sole-plate.

Where a ring of teeth is bolted round the shrouding, much care is necessary in the preparation of the pattern. Without due care the segment castings may come out long or short; they may be atwist, their ends may not be radial, and their teeth may not be square—for all of which errors the pattern-maker will be held responsible.

The correct length of the segments is obtained by calculating the length of a chord of the circle* if the wheel be

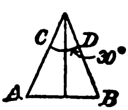


Fig. 355.

* The chord is obtained thus. Find the half angle of the included space betweeen the radii. Get the sine of that angle from a table of natural sines, multiply the radius by the sine. The product doubled gives the required length of the chord. Thus, let it be required to know the length of the chord A B, Fig. 355, A B being the twelfth of a circle whose diameter is 16 feet. The angle at C D is 30°, one-half of which is 15°. The sine of 15° is ·25881. The radius is 8 feet. Then ·25881 × 8 × 2 = A B = 4′ 1·69″.

large, or by striking out a portion of the entire ring, say $\frac{1}{8}$ or $\frac{1}{4}$, if the wheel be small, and giving the segment its proportional part of the arc thus struck out. We allow for fitting on the ends of the segments, which with all due care may vary $\frac{1}{8}$ or $\frac{1}{4}$ inch in length in the castings. The allowance is made for chipping by means of narrow strips ("chipping strips") about $\frac{3}{4}$ inch or 1 inch wide, and they are made thick enough to allow for all possible variation in the casting, say $\frac{3}{8}$ inch in this case at each end, and of this amount at least $\frac{1}{8}$ inch is allowed at each end over and above the finished length of casting, to be taken off by chipping. And as the shrouding plates are not likely to be true, and the segment may become rammed winding, we also put chipping strips on the bottom face of the segment, giving a similar allowance there for fitting.

This ring may be either internal or external, according as the teeth are on its inner or outer curve; but in either case the pattern is made as follows:—

Having struck out the segment in plan (Fig. 335) to get the

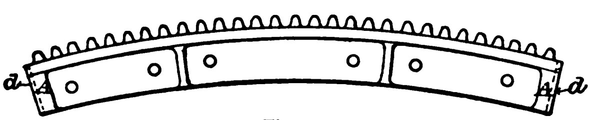


Fig. 335.

ends truly radial and the teeth of the correct shape, and in section also (Fig. 336), we prepare segments for the purpose of building up the sweep. The plate of the segment (Fig. 336, *a*) can be made either in one piece or in two or three sets of sweeps, the latter being, of course, the better method of the two. The thin portion, or the rim, will be made in segments, ceasing at *b*, just where the hollow, *c*, commences. The thickness which forms the hollow, *c*, will be cut out separately—then these three parts, the plate, the rim, the hollow—each distinct and separate, but gauged to thickness, will be screwed together temporarily in the rough. The segment, though rough externally and internally, is at this stage complete in its thickness and ready to receive the lines.

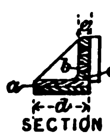


Fig. 336.

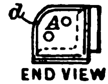


Fig. 337.

Strike the line* on one side for that curve of the ring on

* When striking large radii a trammel-rod is apt to spring and cause a wavy line. In such cases it is better to screw a couple of straightedges

which the teeth are to be fastened, and mark the ends radially from the centre of the curve so struck. Remove to the vice and plane these ends square with the parallel planed top and bottom faces. Then laying the segment on its face upon a true bench or drawing-board, square over with set square the curved line just struck on to the opposite side, and mark the sweep again on that side also. Work this sweep from one side to the other, roughing with gouge and finishing with planes. We have thus a true curve for the attachment of our teeth, at right-angles with the base of the segment. Now, taking out our temporary screws, we can gauge each of the separate portions of the segment, the plate (Fig. 336, *a*), the rim, *b*, and the hollow, *c*, and work them separately—returning them into position and gluing and screwing permanently when done. We shall work the teeth in a box (Chap. II., p. 22), and glue and brad on. The segment ends, A, A, Figs. 335, 337, will be fitted into the angle formed by the plate and the rim, and their chipping strips, *d*, *d*, fastened on, excepting the one in the bottom, which will be skewered. Holes in the ends for bolting the sweeps together will be taken out with pocket prints.

Turbines (Fig. 338) are not yet so extensively come into use in England as in Continental countries. They vary much in design, but differ essentially from water-wheels in that the axis is vertical, and the turbine therefore revolves in a plane parallel with the horizon. The principal type is that which consists of an inner ring of guides, A, A, and an outer ring of buckets, B, B, usually in two or three vertical tiers connected with shrouding, *a*, *b*, *c*, *d*. Turbines being very small in comparison with water-wheels, both the buckets and their shroudings are formed in one casting, the guides and their shroudings being also formed in the same way. Now if we look attentively at our ring of buckets (Fig. 338, plan B), we shall

together like Fig. 354, and slide them around two fixed pins set in the course of the circle at the extremities of the chord, and with a scriber held against the apex describe the circle. The condition is that the height of the triangle measured from the chord shall be equal to the versed sine of its circle, which versed sine is obtained thus:

$$V = R - \sqrt{R^2 - C^2}$$

In which R = radius
C = semichord.

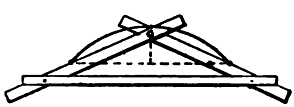


Fig. 354.

I prefer this to the methods of intersecting lines given in books on geometry.

see that the labour of making a pattern would be immense. To cut the shroudings and all the buckets would be a roundabout task. But the buckets being all alike, cores sufficient

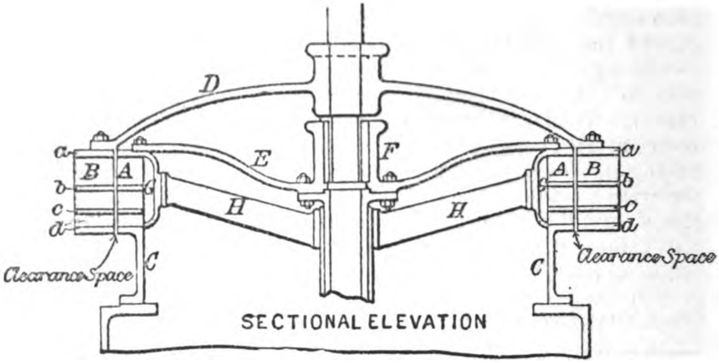


Fig. 338.

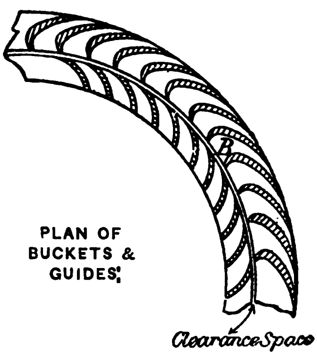


Fig. 338.

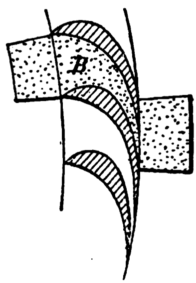


Fig. 339.

for an entire course of buckets can be made from one core-box (Fig. 339); and if there are two or three courses, we need but two or three core-boxes, in which core-boxes the shrouding can also be made. Considering again for a moment, we see that not only will no pattern be necessary, but that no prints for these cores will be wanted, for if the cores be made to fit one another closely without and within the circle of the buckets, they will close up the mould (Fig. 340). Then all we need do is to strike two circles corresponding with the inside and outside ends of the cores, C and D, upon a sand-bed, and to set the cores by these lines. Having thus cleared the way, let us go into detail.

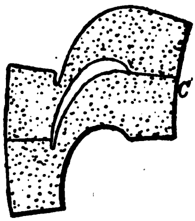


Fig. 340

Fig. 341 illustrates the way in which the core-box is made. Construct a plain rectangular core-box, as indicated by the outer lines. Into this fit sundry blocks, *a*, *a*, *a*, *a*, to part at *b*, *b*. Make a templet of the core in thin wood, and laying it on one side of these blocks, scribe round its edges upon the box face. Open the box, square down in the joint, place together again and scribe off from the templet on to the other side. The box may then be pared and planed through. We might make the box of the entire depth of the three rows of buckets with their

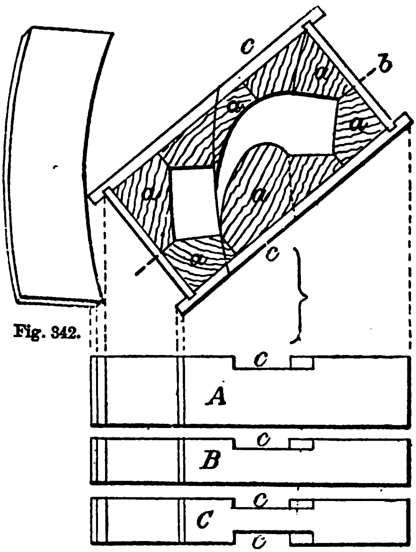


Fig. 342.

Fig. 341.

shrouding, but that would cause inconvenience, since the intermediate shrouding, or rather plating, would be formed through the heart of the core, and being only $\frac{1}{4}$ inch or $\frac{3}{8}$ inch thick, there would be no chance to get at it for the purpose of cleaning up or blacking; so we prefer to make as many core-boxes as there are rows of buckets, A, B, C.

Then for the shrouding we get out sweeped pieces (Fig. 342), corresponding in section with the shrouding and plating, and having marked carefully their concentric positions on the faces of the boxes we cut out recesses, *c*, *c*, *c*, *c* (Fig. 341), on those faces for their reception. Hence, when a core is made, say core A, it presents the appearance of Fig. 343. When the three rows of cores are made and put together we get two shrouds, two plates, and a metal space between contiguous cores. The cores being arranged in a circle, sand is rammed around them to afford support, and a loam top covers the

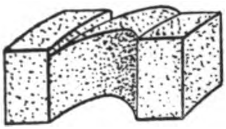


Fig. 343.

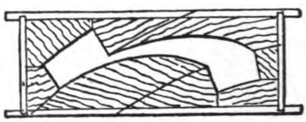


Fig. 344.

whole. The metal then flows between the cores to form the curved partitions between the buckets, and through the cores to form shrouding and plating, while at the outer and inner terminations of the buckets its flow is arrested by the abutting ends of the cores.

The same method is adopted for making the ring of guides, in which the core-box will be shaped like Fig. 344. The cylindrical seating for the governor, with its flange for bolting to the inlet pipe (Fig. 338, C, C), is shown cast in a piece with the guides, and for this two boards, shaped respectively like the Figs. 345, will be made, the seating being cast uppermost.

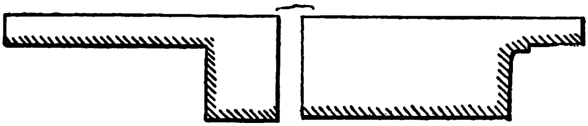


Fig. 345.

The dished plates (Fig. 338, D, E), to which the buckets and guides are respectively bolted, would be made from patterns if small, but struck up if large. Either greensand or loam may be used in the latter case. If greensand, the boards will be cut as in Fig. 346; if loam, like Figs. 347, 348—the difference between the two being as follows: In a struck-up greensand mould the top board cut to the dotted line, *a*, *a*, *a*, *a*, in the Fig. 346, strikes a bed of hard rammed sand, which, being sprinkled with parting sand and covered with a top box has a reverse sand mould rammed upon it, a thing easily and constantly being done, since the lower sand is rammed sufficiently

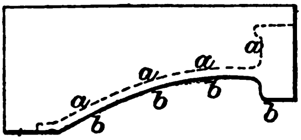


Fig. 346.

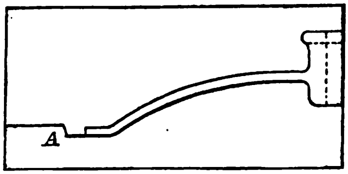


Fig. 347.

hard to resist the thrust of the hand-rammer. This being lifted away, the board cut to the full line, *b*, *b*, *b*, *b*, strikes out the thickness of metal to the bottom edge. The top box then closes this bottom mould for casting.* The disadvantage of this method is, that square edges—that is, edges of sand standing approximately vertical—cannot be lifted in greensand without becoming torn away and broken down, so that mending up with sweeps becomes necessary. Where this occurs the best way is to make the board to strike the edge at

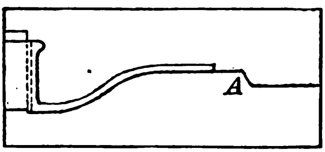


Fig. 348.

Fig. 349.

an angle from which the sand will lift without fracture, ram the top box on that, and then make the edge in the top square with a sweep. We then have an unbroken lower edge by which to guide the mending-up sweep (Fig. 349). The advantage of adopting a greensand mould is, that the time occupied in bricking up and drying are both saved—items of so much importance that a loam mould which would occupy perhaps four days in making could be done within a day in green-

* For another example of a struck-up greensand mould see Chap. VI., p. 40.

sand. There is of course a large class of foundry work which must be done in loam; but where the option lies between the two, the difference in cost will induce us in such cases to decide in favour of greensand.

A comparison of the figures illustrates the difference in method, for in the loam mould the boards strike the actual opposite faces in both top and bottom,* while in the greensand the bottom face only is directly struck. When the moulds are closed, the checks, A, A, insure their concentricity.

The guide-ring plate, E, carries the step bearing of the turbine shaft (Fig. 338, F), and the step of a turbine is lined with strips of lignum vitæ (Fig. 350), which, with the water for a lubricant, answers better than metal. These strips are driven tightly into grooves, *a*, *a*, *a*, cast in the boss (Fig. 351). These recesses, if cut out in the pattern, are so deep, and the spaces between them so slight, that they would not deliver from the sand. Hence we core them out, as indeed we should do in the case of any other recesses or pockets where accuracy is required. But neither could we put prints around the inside of the boss, since the thin sand between their edges would not hold together. So the correct way is to put a round print upon the centre of the boss just as though there were nothing but a perfectly plain core wanted. Then we make a core-box for the recesses, distinct from the main central core, of course with no print allowance, and the sides of this should have a shade of taper from the upper end, so that the strips shall have a tendency to tighten as they are driven down. When the cores are dry the pattern-maker marks off as many equal divisions on the central core as there are to be recesses in the casting, and nails the recess cores upon the central one (Fig. 351), which is then ready to be dropped bodily into the mould.

Fig. 350.

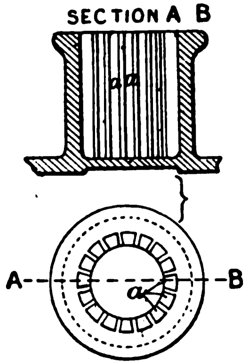


Fig. 351.

The pattern-maker is also expected to fill in the lignum vitæ blocks, and this should be effected with as little waste of

* See also Chap. X.

stuff as possible. The best plan is to cut the stick down with a circular or frame-saw to the thickness required, and then, having fitted a templet strip into the casting and made the necessary allowances for turning and facing, to mark out the thicknessed stuff from that. Once sawn out, the pieces should be kept in a cool place or in water while being worked up, as lignum vitæ is particularly liable to shake in the joints of the annular rings. When driving in, care should be taken not to strike on the shoulder (*a*, Fig. 350), or it will infallibly split off. When all are driven in, the step will go into a lathe having a slide-rest, to be bored and faced.

The governor-guide (Fig. 338, G, G), is either cast in a piece with the arms or bolted to them afterwards, the latter plan being preferable. A small guide would be cored out with

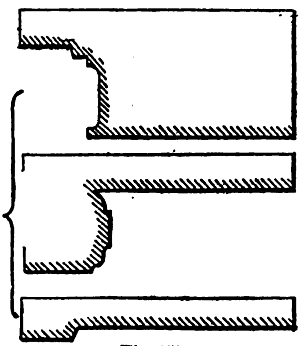


Fig. 352.

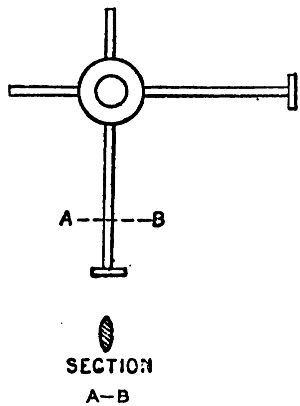


Fig. 353.

segmental cores, a large one struck in loam, for which the boards will be like Fig. 352. The arms (Fig. 338, H, H) are planed up oval-shaped and mortised into the central boss (Fig. 353), and have their flanges screwed on, everything being fast, and the moulder joints down to the centre of the oval section.

CHAPTER XXXI.

BOILER FITTINGS AND MOUNTINGS.

Dead-plate.—Marking and Filling.—Fire-bar.—Allowance for Play.—Bearer.—Door Frame.—Building up of the Pattern.—Door.—Valve Seatings.—Safety-valve Shell.—Valves.—Sweeped Fire-bars.—Mud-hole Door Frames.—Man-hole Frames.

LANCASHIRE and Cornish boilers are fired internally, the latter being constructed with a single furnace tube, the former with two, and with cross-tubes besides passing through the furnace. The pattern-maker has to prepare dead-plate, fire-bars, furnace front and door, seatings and valves, and other attachments. Some of these have to be fitted to the boiler, and a few general hints relative to these matters may very properly be borne in mind.

The dead-plate (Fig. 356) is that portion of the fire-grate surface lying just within the front end of the boiler, and it ranges from 9 inches to 15 inches or 18 inches in width, according to the capacity of the boiler. It slopes downwards and backwards, and either rests upon angle iron brackets fastened to the sides of the fire-box, or simply against the boiler sides. In order to fit it correctly, the workman marks its position at the boiler front, and also the amount of drop or slope which the fire-bars make where they abut against the

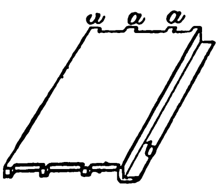


Fig. 356.

bridge (about 1 in 10), and straining a chalk line between these points, strikes the line of slope on each side of the fire-box. To these lines the dead-plate pattern is fitted, and a few chipping strips, *a*, *a*, sufficiently thick to compensate for the contraction which the plate will undergo, and to allow of a little fitting besides, are fastened upon the ends. At its front end the plate either abuts against or rests upon a flange upon the fire-door frame, and at the back it is recessed, *b*, to receive the ends of the fire-bars.

The fire-bar is a simple pattern of the annexed shape, Fig. 357. It is tapered in section to allow the ashes to fall freely downwards, while the upper portion is left parallel to

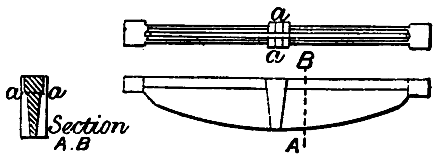


Fig. 357.

keep the air-space parallel and equal during the burning down of the bars. The central thickness pieces, *a*, *a*, are put there to prevent the twisting of the bar sideways. Bars like this, when made in quantity, are usually made from iron patterns, which are moulded by simply bedding in. Fire-bars should never be made a tight fit, as they expand permanently with the heat, but a play of about 1 in 24 should be given at the ends. The cast-iron bearers for the bridge and for the fire-bars are made of an L or T section, and are fitted similarly to the dead-plate, Fig. 358.

A fire-door frame is shown in plan, and in section in Fig. 359. The plate, A, is framed together with segmental pieces and half-lap joints, preferably to cutting it from a single piece

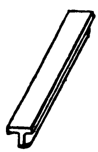


Fig. 358.

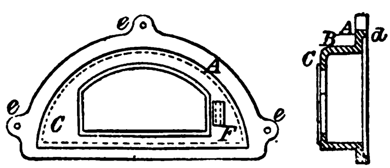


Fig. 359.

of stuff, since the taking out of the central portion would leave short grain at the sides. The hooded portion, B, is glued up with thin segments, cut through with gouge and chisel and screwed upon the plate. The front, C, is halved together with half-lap joints, and screwed to the face edge of the hood. A narrow chipping strip, *d*, is run round in segments on the face which bolts to the boiler, of sufficient depth to clear the rivet heads, and a thin facing is bradded to that portion upon which the door folds. Lugs, *e*, *e*, *e* for attachment, and, a lug, F, on which the door hinges, cored out with pocket prints for the hinge pin, completes the pattern.

The pattern of the door (Fig. 360) consists of a thin plate, having a couple of hinge lugs and a thin facing on the front for chipping. Provision will often be made for draught by a revolving ventilator or a sliding grid, the holes for which are cored out. If the fire-hole opening is wide, a double door is used in preference to a single one.

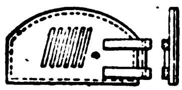


Fig. 360.

Seatings for the valves and cocks are made in cast iron, and riveted to the boiler. Fig. 361 shows the pattern of a seating of this kind. It consists simply of a curved flange, A, and boss, B, having T-headed recesses cast in. The flange may either be fitted to the boiler direct, or a thin templet of wood may be cut to the curve of its diameter, and the pattern worked with a templet cut the reverse of this. The flange itself is made distinct from the boss part, and the two screwed together afterwards. The stuff for the flange being planed to a parallel thickness, the hollow face should be planed first, and the rounding side gauged and cut with a chisel afterwards, remembering that the rounding of the flange should blend into a hollow around the flat face on which the boss is to be secured. On this boss, plain, square prints will be nailed, and a core-box shaped like Fig. 362 will take out the T-headed recesses.

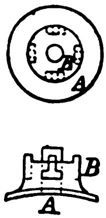


Fig. 361.

Fig. 362.

The shell of a safety-valve consists of a plain, double-flange pipe, with or without a branch for the steam-pipe, depending upon whether the steam is taken from the valve or no. Or, if

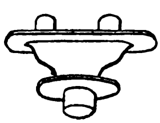


Fig. 363.

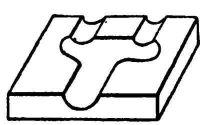


Fig. 364.

Fig. 365.

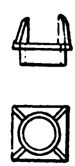


Fig. 366.

there be two valves, as in large boilers, it consists of a double bend pipe (Fig. 363), a core-box (Fig. 364) being necessary with the latter. The valves may be flat disc (Fig. 365), maintained in position with guides attached to the seating

(Fig. 366), or mitre, with three or four wings (Fig. 367), having either a top pin, A, or a recess to produce unstable equilibrium, and prevent the tendency to sticking (Fig. 368). The patterns of these valves are all made like their castings,

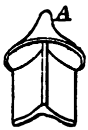


Fig. 367.

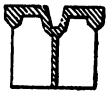


Fig. 368.

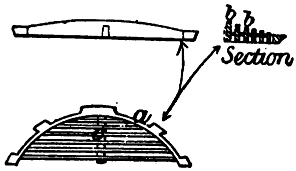


Fig. 369.

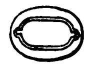


Fig. 370.

the wings being cut separately from the discs and studded on, either fast or loose. Mahogany should be used, and they mould just as they stand when in natural position.

Vertical boilers, for steam cranes and small stationary engines, have fire-bars of a sweeped outline (Fig. 369). These are sometimes cut out of solid mahogany; but the best way is to build up the rim, *a*, in segments, and, having cut that to shape, to fit the bars, *b*, already planed to their thickness, into very shallow grooves, about $\frac{1}{16}$ inch deep, cut in the rim. The connecting strips, *c*, are glued in afterwards. These bars rest upon a ring of wrought iron set in the interior of the fire-box.

Mud-hole doors are fitted opposite to every cross tube and at the bottom of the boiler. These are plain oval castings, held in place with a tightening screw. When the boiler is cleaded, as these vertical boilers often are, the cleading is screwed to a casting made to encircle the hole. These are of the annexed shape (Fig. 370), and being extremely thin, are either made from metal patterns or are cored out. The man-hole in a cleaded boiler has a frame also precisely similar (Fig. 371), but, of course, proportionally larger. For this a wood pattern is built up in segments, and the flat flange which takes the cleading being thin, is curved round and fastened to the built-up portion. But a metal pattern is necessary for durability, and it is cast in iron if for frequent use, or in lead if used for different boilers having different diameters, and therefore requiring some alteration of curvature.

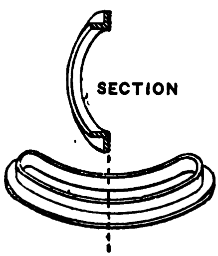


Fig. 371.

CHAPTER XXXII.

WORKSHOP NOTES.

Allowances for Turning and Planing.—Variable in Amount.—Name-plates.—Lead Letters.—Curved Name Plates.—Chequering of Foot-plates.—Stock Core-boxes.—Glue.—How to make.—How to Joint.—Shellac Varnish.—Paint.—Faced and Unfaced Portions of Patterns.—Prints and Bosses.—Pattern Register.—Makeshift Work.—Lead.—Plaster of Paris.—Shop Tools.—Stamping of Patterns.

THE miscellaneous character of the contents of this chapter will render desirable the classification of the subjects under their appropriate headings.

Allowances for Turning and Planing.—The usual practice is to allow $\frac{1}{8}$ inch on iron castings for machining. This allows of two cuts being taken in the lathe or on the planing machine—a coarse first cut and a fine one for finishing. For brass castings one-half only of this allowance is given, $\frac{1}{16}$ inch. But this, though a general rule, is by no means to be universally observed. In a long casting, where there is a probability that it will not remain straight in cooling, more than the $\frac{1}{8}$ inch must be allowed, the precise quantity being regulated by the risk and uncertainty present as to the amount by which it is likely to buckle. In some long, disproportioned castings, the allowance may be as much as $\frac{3}{8}$ inch. Again, in a small engine cylinder, $\frac{1}{4}$ inch in the diameter is ample, but in a cylinder of 6 feet or 7 feet in diameter that would not be enough for safety, owing to the possible inaccuracy of the core and the uncertainty about contraction, and we should allow from $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in diameter.

Then, on the other hand, a small piece of work need not have so much as the usual allowance, because, the surface being small, will only be affected by its local roughness and slight inequalities, instead of by some other portion of the surface two or three feet distant being possibly not in the same plane with itself. Neither is a small casting affected by contraction as a large one is; practically, it does not contract at all, since the rapping counteracts or more than counteracts its small amount.

Again, in set work—that is, work which is repeated over and over again without any variation—we get to know the amount of contraction so exactly, and the least allowance necessary for fitting so perfectly, that we can do with less allowance than it would be safe to allow for in a first casting. We then reduce it to the minimum, so that expense may be lessened in the turning and fitting shops.

Name-plates.—These are attached to all work leaving the shops. They are cast in iron or in brass. The letters put upon the pattern are first cast in lead or tin, what are called "block letters" being preferable, because easier to prepare, and not difficult to mend up if they tear the mould. They have a large amount of taper on their edges, and are fastened upon a wooden plate, which is usually surrounded with a narrow fillet-strip to improve its appearance. The letters are cast from metal patterns purchased for that purpose, and sold in many different sizes. The pattern-maker, in that case, has to file them up smoothly for moulding. Or they may be purchased by the gross already filed and ready for use. Common shellac varnish, especially if thickened with a little powdered chalk, will hold them very firmly; but, if for permanent use, small upholsterer's gimp pins, or pins still smaller but of the same shape, sold for the purpose by the letter-makers, will render them more secure. Larger lead letters, however, say from 2 inches upwards, will be screwed on the plate.

If a name-plate has to fit a curved or crooked casting it will be made straight in wood first, then cast in lead and bent to shape, and the mould made from the lead pattern. It will be as well to make a bottom board of the same shape to support the lead pattern during the ramming up. Or the pattern will be made straight, cast in yellow metal or soft brass, and bent then to the curve direct. Sometimes the maker's name, instead of being bolted to, is cast in a piece with the work, the letters being put upon the pattern if cast in a vertical position. But if on the side where they would not deliver, the name-plate is put into a core-box, and the core dropped into a print impression made for its reception.

Chequering.—The chequering of cast-iron foot-plates for boiler-rooms, &c., is not always done, as many would suppose, in the pattern. The time required for making and nailing on the lozenge-shaped diamonds on a foot-plate is most deceptive. Hence the method commonly adopted is to nail a double row of "chequers" on a strip of wood, Fig. 372, and to stamp it

Fig. 372.

in the mould, the hinder row of chequers dropping into the front row of impressions last made, and so forming the guide for the next row.

Many items are kept in "stock" in a well-ordered establishment. Core-boxes for making plain round cores are thus always kept on the foundry shelves. A good set should run from $\frac{3}{8}$ inches to 5 inches or 6 inches in diameter, advancing by eighths in the smaller sizes and by quarter inches in the larger ones. They are made in cast iron, fitted as shown in section, Fig. 373, and bored out true in the lathe. Cores larger than these are oftener made from wooden boxes, or are

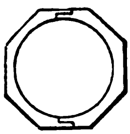


Fig. 373

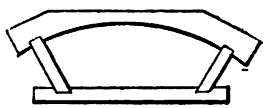


Fig. 374.

struck up on a core-bar. Where the iron pattern rings of pulleys are kept in stock, large cores may conveniently be made from them; or if very large—say over 18 inches or 24 inches—from segment boxes (Fig. 374), six or eight to the circle. Square wooden core-boxes are also kept in the foundry. Small prints are kept in all their sizes; and instead of bradding them on, it is much better to have a standard "stud-bit"—*i.e.* a centre-bit of $\frac{3}{4}$ inch or $\frac{1}{2}$ inch diameter—and to turn studs on all prints to this size, by adopting which method they will be always readily interchangeable.

Glue.—Glue must be kept free from dust and dirt in a clean box. When required for use, the pieces should be washed in cold water, broken up small with a hammer, and dropped into the middle pot with sufficient clean water to cover them well over. The bottom pot being about three parts filled with water is then put on the stove and simmered, the glue being stirred from time to time with a stick, and the scum which rises ladled off and thrown away. Too great a temperature should be avoided, for that would burn the glue and impair its adhesive power. A small cast-iron tank supplied with hot water from the waste-steam pipe of the engine affords a better means of heating the glue than a fire, because then the temperature can never exceed that of boiling water.

Glue joints are made either with the trying plane or with a longer plane called a "jointer." One face, or edge, as the case may be, is planed true first, and chalked, then its fellow is fitted to the chalked portion. Where the joint is long, two men rub it alternately backwards and forwards to work out all the superfluous glue and air, and "set" it when it becomes difficult to move it any more. The pieces thus jointed are sometimes secured with cramps, sometimes with staples or with weights, or are simply left to themselves—all dependent upon the character of the work. Thin pieces having large superficies—thin segments, for example—have a tendency to curl upwards, the joint opening along the edges, owing to the swelling action of the moisture. Damping the upper surface with hot water from the outer pot counteracts this tendency.

In winter-time the joints of the pieces to be glued should be warmed, else the glue will chill, and never set properly. The "thickness" or consistence of the glue is regulated by the amount of water present, and should vary with the character of the work, end grain joints or joints running obliquely to the grain requiring thicker glue than those along the grain, and small stuff taking thicker glue than stuff having a large area. Both of the joint faces of the wood operated upon should receive an application of glue from the brush. From one and a half to three hours is sufficient to allow of the drying of the joint, more in winter than in summer, though it is always better where practicable to give an unassisted joint a night to harden.

Varnish.—The varnish of the pattern-maker is made by dissolving pale shellac in wood naphtha or in methylated spirit, in the proportion of about two pounds to the gallon. The spirit should be pure, for if there is water present the varnish will dry white and streaky. While dissolving, it should be kept in a warm place, and shaken from time to time, or stirred with a clean stick. No other ingredient is put in, and the varnish is laid on with a brush only. When dry, the grain of the wood presents a hard rough surface which is glasspapered down, and another coat of varnish is laid on, two coats being the usual number for ordinary patterns, three sometimes for better work. When a large number of castings are wanted from one pattern it is true economy to preserve the grain from the action of the damp sand by a liberal application of varnish.

Paint is often used in preference to varnish in the case of large patterns. It gives a harder skin, is cheaper, and if plenty of "driers" is put in it soon hardens.

We have referred several times to the upper and lower parts in moulding as affecting planed and turned metal faces. The moulder, in most cases, would not be able to distinguish the one from the other in classes of work to which he was unaccustomed. Hence it is the custom in some shops to indicate the faced and unfaced portions by distinctive colours. Thus, if the pattern were varnished with yellow shellac varnish, the portions faced might be coloured black or red. This practice is often extended to distinguish prints from bosses, which are sometimes confounded by the moulder, cores being put into bosses, and prints being cast on. Then a third colour would be adopted for all prints.

Further, to prevent mistakes, and to keep a pattern register on the pattern itself, a printed label is sometimes stuck on, containing sundry items—as for instance, "Pattern number, *A* 840; Number off, *Two; Cast, this side down.* Name of pattern, *Steam-chest.* For, 12-*horse engine*," and perhaps the initials of the foreman are added. Or a kind of cheque-book is kept by the foreman, and a written order from that book given loosely with the pattern to the foreman moulder, the counterfoil being kept in the pattern-shop. This might contain, "*date, order number, number off, name of pattern.*" In shops where little system is observed, because a very limited amount of work is done, it is usually considered sufficient to *chalk* on the pattern 1 *off,* 4 *off,* 12 *off,* as the case may be, and to give special instruction by word of mouth.

Work of a makeshift character often has to be done in the pattern-shop and foundry. Castings are frequently renewed without a wood pattern, the broken or worn casting, as the case may be, being made to do duty as a pattern. Where this is the case, all dirt and grease (which would cause the sand to stick) is burnt off; parts that would not mould by reason of their being undercut are filled in with prints, and core-boxes made to take out the undercut portions. Holes are filled up and printed; contraction, if the casting be large, is allowed for by thin strips of wood laid against the ends. Allowances for turning and planing are made by thin slips of wood, or of lead if the surfaces where the allowances are required happen to be curved. Broken wheels are often replaced in this manner, new patterns being expensive. The broken teeth are made good by the pattern-maker, the wood being fastened to the metal with thick shellac varnish, and a couple of mending-up teeth provided to make good any falling down of the mould. These broken castings require varnishing in order to draw from the sand.

Thin sheet lead is very useful in the pattern-shop for lining up the patterns of brasses or other bearing parts in order to accommodate them for a smaller bore, for thickening up curved faces where it would be difficult or impossible to bend wood, or for increasing by a slight amount the diameter of a pattern—as, for instance, that of a flange or small rigger. The lead is fastened on with fine screws or with brads. For lesser increments of thickness limp cardboard or thick brown paper are serviceable, attached either with glue or shellac varnish. Plaster of Paris, too, is almost indispensable in the shop. In small work of a temporary character a pattern, or some portions of a pattern, or an alteration to an existing pattern, can be made in a few minutes with plaster, which alteration would take a very much longer time if done in wood. And since its purpose is but temporary, it is of no consequence if the plaster becomes broken on leaving the mould.

There is a good deal of rough work, as well as some of the very best, done in the pattern-shop. As a rule, the men who do the one class are not employed to any great extent upon the other. Among the rougher class of work shop tools take an important place, and in a large factory there is always sufficient in this line to keep one man constantly employed. There are boxes and turn-over boards for the foundry, special chucks and templets and setting blocks for the turners and fitters, bending blocks for the boiler-makers, and dies of all descriptions for the smiths. Much special knowledge is required in this work—little "tips" and "wrinkles," as the workmen say—and certain allowances, all essential to the perfection of results. So that, after all, the term "rough" rather implies an absence of "finish" in the patterns than a slight equipment of technical knowledge or absence of accuracy. For rough work as applied in this sense a foreman or employer will provide special timber. While he will use the very best quality board that can be got for the best and standard work, he will provide a certain proportion of seconds for the rougher work of shop tools, core-box sides, boxed-up patterns, and loam-boards.

All patterns should be stamped before they go into the pattern stores. They may be stamped by the name of the piece of work to which they belong, or by some distinctive number, which number is kept in a pattern register, or with both together thus: "4IN. THREE THROW PUMPS. B 482." The letter B has this reference: when the registered patterns have reached a certain number, say, 1,000 or 10,000, an increase in the number of figures is apt to cause inconvenience. Hence, there would be A 1, A 2, &c., up to the limit, say A 1,000; then B 1, B 2, as far as B 1,000; afterwards C 1, C 2, to C 1,000, so that 26,000 patterns might be thus registered. The system is an excellent one, and is largely adopted. The drawback is, that when patterns have been repeatedly altered, as they very often are, for modifications of design and difference in dimensions, these registers become comparatively valueless unless a very complete record of such alterations is kept in the pattern register itself.

CHAPTER XXXIII.

THE QUALIFICATIONS OF A PATTERN-MAKER.

Specialisation of Work.—Woolwich Arsenal.—Mental Loss suffered by Machine Hands.—Variety in Pattern Work.—Book Knowledge.—Need of Technical Education.—The Relation of Study to Work.—Principles and Practice.—Projection.—Arithmetic.—Experience.—Antiquity of Pattern-making.—Its prospects.

THOSE who have perused the foregoing chapters will have observed that I have not written to give instruction in the manipulation of tools and timber. Such instruction could only have been imparted at the sacrifice of an equivalent of that more advanced knowledge which I have striven to embody therein. I have therefore assumed that those who would read this work were already in possession of a certain amount of elementary instruction in workshop practice. Hence I have written for the apprentice who has learned the first lessons of his craft, for the young workman whose experience has been limited and opportunities few, for the draughtsman who finds himself sadly crippled in designing new work through lack of knowledge of pattern-making and moulding, for the amateur who has learned how to handle tools and has a smattering of engineering construction, and also, I trust, for those workmen—a large class—who, in these days of extreme specialisation, have been accustomed to one kind of work only, without enjoying the opportunity of learning aught of any other. There are many men who, having been trained in a shop where special work only is done, cannot readily turn their hands to any other branch. In their special groove they get along very well; at all else they prove incompetent, simply on account of the initial difficulties which a little instruction would enable them to surmount. This evil increases year by year, and the praise a fitter once bestowed upon a fellow-workman, to the effect that he was "a first-class slide-valve hand," bears testimony to the manner in which work is being cut up, to the advantage of the purchaser, but to the corresponding intellectual disadvantage of the workman.

Take Woolwich Arsenal, for example, as a type of many a smaller factory. There, though one cannot help admiring the ingenuity displayed in the designing and perfecting of the numerous and valuable time-saving machines in use throughout the place, there is a mournful feeling that the workmen, unless their intellectual character be developed in some way or another outside and independently of their daily labour, must degenerate in time into mere machines also. Think of the mental loss suffered by the man who has to cut the dovetails in the ends of the cartridge-boxes all the year round—who does not even cut them by hand, but merely presents those ends to the automatic machine which takes them out. Or that mental *ennui* which must be endured by the man of monotonous occupation who glues these dovetailed corners together perpetually—pile after pile, hundreds of boxes in succession—from whose sense of responsibility even the risk of making a bad joint is eliminated by the use of a parallel screw clamp of metal. This mental loss is one factor in the heavy price we have to pay for our industrial superiority; hence the greater need for the cultivation of those technical, scientific, and literary aids and recreations which are now happily within the reach of every one.

This is somewhat of a digression, but it illustrates in rather an extreme manner the injury which our modern subdivision of labour does to the workman by robbing him of a useful range of experience—injury, not only because it renders almost unnecessary the continual exercise of his faculties, but also by making him incapable of accepting any other situation save one involving precisely the same routine of automatic labour as that to which he has been accustomed. Now, in the case of the pattern-maker, this danger does not exist to anything approaching the like degree, because even in a shop where but one class of work is done, whether it be locomotive or marine engines, cranes, pumps, or anything else, there is much variation in the different patterns for the different parts. But still there are very few shops indeed in the kingdom where the range of work done is so extensive as that which these chapters, now concluded, have embraced. Consequently, there are numbers of pattern-makers and draughtsmen who have never had a practical knowledge of so many classes of work. And now, having thus far treated of the general principles involved in those various types so fully that I think it would be impossible to name any special piece of work to which those general principles of construction would not apply, I propose devoting a last page to the discussion of the mental training which should proceed coincidently with the practical work of the shop.

Now I am not going to frighten my ambitious fellow-workmen who are desirous of becoming first-class craftsmen by marshalling before them a long array of studies. Book knowledge is not indeed really necessary, for I have known excellent workmen who were comparatively illiterate men; but then they were incapable of ever becoming anything more than mere men at the bench. But the time has gone by, I think, when the majority of young men were content to labour without an aspiration beyond journeyman's wage and the coming Saturday night. The workman's mental horizon has expanded, and the pleasures of literature and the marvels of the wonderland of science occupy the leisure which was once idled away in the streets or the public-house. And now, as ever, though the average man may not rise above the ranks, he is appreciated the more if he has learned the fundamental reasons of things, and so can proceed intelligently at his tasks.

But even when working at the bench no man knows how soon he may be thrown upon his own resources for rough, and, ready design. There is many a comfortable shop where one or two pattern-makers are kept for repairs, and where there is no draughtsman or designer—no one who can render him the least assistance. Yet if a man proves himself competent to cope with emergencies as they arise, and can do a job quickly and substantially without extraneous assistance, he generally has employment so long as he cares to keep it. So, too, in many pattern-shops a working foreman only is kept, and the men have much more scope for the exercise of their talents than in those larger establishments where draughtsmen and foremen arrange everything for them. In general shops again, the workman will often have new and strange jobs given him to do, unlike any that have been done in the shop before, for which he should be prepared by a study of the principles bearing thereon. In repair and jobbing shops, also, workmen, as well as foremen, are sometimes sent out to receive instructions relative to break-down work and proposed alterations. For these, and many more reasons, the pattern-maker's craft is not so easy of mastery as many others are, and it should be his aim to prepare himself for contingencies that may arise in the routine of bench work, and for duties which, if he ever becomes foreman, he will be called upon to perform every day.

It is of no use to think of becoming a good pattern-maker without becoming also, to some extent, a good engineer. A man ill-informed in the principles of design hesitates how to proceed with a new piece of work, or whether to proceed with it at all without calling in some extraneous assistance, simply because he does not know the elementary principles on which his work is based. A knowledge of the elements of geometry or mensuration would often enable him to mark out and cut away his stuff at once, instead of working slowly and doubtfully in the dark. A clear knowledge of the uses to which his work is to be put will enable him to bestow greater care on parts where the greater accuracy is desired, and to bestow less labour on the unimportant portions, and a knowledge of the mechanical laws on which his trade is based will give him a vast increase of interest in the details of the workshop. How delightful to the worker who has also become a student to see for the first time in books those things with which he has been familiar in the workshop, without knowing the why and the wherefore—to see them explained and illustrated, and to learn that the principles of his dull craft are founded on laws as immutable as those which guide the planets.

Briefly noting the studies by which he should qualify himself for his trade, first in the list of his requirements comes the statical portion of mechanics. Here he should well understand the Parallelogram of Forces, with its modifications of the triangle and polygon; the principle of the lever, and the methods of calculating leverages, since these have their applications in screws, gearing, belting, girder calculations, weighbridges, and so on. He should also be conversant with the fundamental properties of fluids, as bearing on liquid pressure and the flow and efflux of water; also of atmospheric pressure as affecting the construction of pumps and of steam-engines. Heat, also, as bearing on the expansion and contraction of metals, the warming of buildings, the economy of the steam-engine, and its equivalent in mechanical work should be studied. Mensuration of superficies and of solids is also a necessary acquirement, as are likewise the commoner problems in plane geometry. And now that electrical engineering is coming to the front, he might find it to his advantage to understand the principles of dynamical and statical electricity, and their application in the construction of the dynamo. All these will be studied best in the elementary and advanced classes held in all important provincial towns in connection with the South Kensington Department—supplemented, of course, by home reading. Neither will the pattern-maker find it so difficult to master the knowledge of these things as an unpractical person would do. For he sees the applications of their principles around him every day of his life. They are so perpetually before his eyes that he too often fails to observe or to regard them. He has only to walk through the factory with his eyes open to see dozens of instances of the application of the principles enunciated in his books. Hence, what is so dry and difficult of application to the mere student becomes instinct with life and fact, and plain and practical, to the observant workman.

A knowledge of drawing is one of the chief requirements of the pattern-maker. And by this I do not mean merely a skill in making drawings from copies. A mere tracer can do this after a few months' practice, without possessing any knowledge of that which his drawing represents. But by drawing I mean the principles of projection as applied to geometric figures, in plans, elevations, sections at various angles, and so forth. Mere copying of the so-called mechanical drawings provided in the schools of Art is of little or no value; but the student who has thoroughly mastered the principles of projection will never experience any serious difficulty either in making or in understanding an intricate drawing. The leisure of a few months devoted to this subject will be of invaluable service ever afterwards. Most of the drawing which the pattern-maker has to do is done to full size upon a chalked board, and therefore minute proportion and finish are neither looked for nor are they necessary. But he will be able to see through an intricate small-scaled general or detailed drawing rapidly and accurately, when he is thoroughly conversant with the principles by which its various views are projected.

The scientific knowledge of the studious worker has to be put to practical use, and for this information of a more technical character must be acquired. Knowing, for instance, how to calculate the strains due to the leverages in a certain piece of work, we also require to know something about the strength of the materials which enter into engineering construction—iron, gunmetal, copper, oak, red deal, pitch pine, &c.—and how to combine these with our arithmetic in the shape of multipliers, coefficients, &c., for tensile, compressive, and shearing strains. A knowledge of how to read the simpler algebraic formulæ—that is, the meaning of signs, brackets, associations of quantities, &c.—is necessary, though algebra and trigonometery themselves are not required in the pattern-shop. Common arithmetic will enable the workman to perform all the calculations he will have to do; and by common arithmetic I mean the elementary rules, together with proportion, decimals, and evolution of the square and cube roots.

Lastly, there is that experience which, in the course of time, bears the semblance of intuition—that experience which comes of close and long-continued observation, and is invaluable to its possessor. Such intuition is far superior to mere book learning—infinitely better than an exhaustive study of all the text-books without it. Yet when the two are harmoniously combined, the result is a full and ready workman who keeps his situation through slack as through busy times, because he has rendered himself so valuable to his employers that they are loth to let him go. Such it should be the aim of every workman to become, and even though he may not perhaps attain the highest prizes, he can never receive that contempt which is awarded freely to the indolent and incompetent.

I have ever loved the trade of my choice. I prefer it to any other with which I am acquainted, and I like it mainly because of the variety of employment which it affords, embracing as it does the whole range of the engineer's knowledge, designing, moulding, fitting, and the application of many branches of science beside. It would not do for us all to think alike; but I should not like to be making table-tops all my life, nor framing chests of drawers together year after year, nor French polishing till my hair turned grey. I love this trade because the continual change of work requires a constant exercise of the mental faculties, at once pleasing and healthful, and invests subjects apparently dry with an ever-new interest. My pattern-making is also of very high antiquity, since some Neolithic fellow-craftsman must have modelled the pattern of the metal mould, with its gate and runner and dowels, from which the first bronze user made his first hatchet or chisel of metal. And it can never be superseded, since no machine can ever take the place of intelligence in the construction of patterns whose types and dimensions are seldom exactly alike.

My task is done. From beginning to end mine has been a pleasant occupation. I have striven to make this volume supply a want which I have experienced in former years, and trust that it may be of service to others in years to come. The types of machinery are ever varying, but the *principles* which lie at the foundation of their pattern-making must ever remain the same.

APPENDIX.

Table of Diameters, Circumferences, and Areas of Circles.

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
1/8	·3927	·01227	3 1/4	10·210	8·2957
1/4	·7854	·04909	3 3/8	10·602	8·9462
3/8	1·1781	·1104	3 1/2	10·995	9·6211
1/2	1·5708	·1963	3 5/8	11·388	10·320
5/8	1·9635	·3068	3 3/4	11·781	11·044
3/4	2·3562	·4417	3 7/8	12·173	11·793
7/8	2·7489	·6013	4	12·566	12·566
1	3·1416	·7854	4 1/8	12·959	13·364
1 1/8	3·5343	·9940	4 1/4	13·351	14·186
1 1/4	3·9270	1·2271	4 3/8	13·744	15·033
1 3/8	4·3197	1·4848	4 1/2	14·137	15·904
1 1/2	4·7124	1·7671	4 5/8	14·529	16·800
1 5/8	5·1051	2·0739	4 3/4	14·922	17·720
1 3/4	5·4978	2·4052	4 7/8	15·315	18·665
1 7/8	5·8905	2·7611	5	15·708	19·635
2	6·2832	3·1416	5 1/8	16·100	20·629
2 1/8	6·6759	3·5465	5 1/4	16·493	21·647
2 1/4	7·0686	3·9760	5 3/8	16·886	22·690
2 3/8	7·4613	4·4302	5 1/2	17·278	23·758
2 1/2	7·8540	4·9087	5 5/8	17·671	24·850
2 5/8	8·2467	5·4119	5 3/4	18·064	25·967
2 3/4	8·6394	5·9395	5 7/8	18·457	27·108
2 7/8	9·0321	6·4918	6	18·849	28·274
3	9·4248	7·0686	6 1/8	19·242	29·464
3 1/8	9·8175	7·6699	6 1/4	19·635	30·679

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
6⅜	20·027	31·919	11½	36·128	103·869
6½	20·420	33·183	11⅝	36·521	106·139
6⅝	20·813	34·471	11¾	36·913	108·434
6¾	21·205	35·784	11⅞	37·306	110·753
6⅞	21·598	37·122	12	37·699	113·097
7	21·991	38·484	12⅛	38·091	115·466
7⅛	22·383	39·871	12¼	38·484	117·859
7¼	22·776	41·282	12⅜	38·877	120·276
7⅜	23·169	42·718	12½	39·270	122·718
7½	23·562	44·178	12⅝	39·662	125·184
7⅝	23·954	45·663	12¾	40·055	127·676
7¾	24·347	47·173	12⅞	40·448	130·192
7⅞	24·740	48·707	13	40·840	132·732
8	25·132	50·265	13⅛	41·233	135·297
8⅛	25·515	51·848	13¼	41·626	137·886
8¼	25·918	53·456	13⅜	42·018	140·500
8⅜	26·310	55·088	13½	42·411	143·139
8½	26·703	56·745	13⅝	42·804	145·802
8⅝	27·096	58·426	13¾	43·197	148·489
8¾	27·489	60·132	13⅞	43·589	151·201
8⅞	27·881	61·862	14	43·982	153·938
9	28·274	63·617	14⅛	44·375	156·699
9⅛	28·667	65·396	14¼	44·767	159·485
9¼	29·059	67·200	14⅜	45·160	162·295
9⅜	29·452	69·029	14½	45·553	165·130
9½	29·845	70·882	14⅝	45·945	167·989
9⅝	30·237	72·759	14¾	46·338	170·873
9¾	30·630	74·662	14⅞	46·731	173·782
9⅞	31·023	76·588	15	47·124	176·715
10	31·416	78·540	15⅛	47·516	179·672
10⅛	31·808	80·515	15¼	47·909	182·654
10¼	32·201	82·516	15⅜	48·302	185·661
10⅜	32·594	84·540	15½	48·694	188·692
10½	32·986	86·590	15⅝	49·087	191·748
10⅝	33·379	88·664	15¾	49·480	194·828
10¾	33·772	90·762	15⅞	49·872	197·933
10⅞	34·164	92·885	16	50·265	201·062
11	34·557	95·033	16⅛	50·658	204·216
11⅛	34·950	97·205	16¼	51·051	207·394
11¼	35·343	99·402	16⅜	51·443	210·597
11⅜	35·735	101·623	16½	51·836	213·825

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
16⅝	52·229	217·077	21¾	68·329	371·543
16¾	52·621	220·353	21⅞	68·722	375·826
16⅞	53·014	223·654	22	69·115	380·133
17	53·407	226·980	22⅛	69·507	384·465
17⅛	53·799	230·330	22¼	69·900	388·822
17¼	54·192	233·705	22⅜	70·293	393·203
17⅜	54·585	237·104	22½	70·686	397·608
17½	54·978	240·528	22⅝	71·078	402·038
17⅝	55·370	243·977	22¾	71·471	406·493
17¾	55·763	247·450	22⅞	71·864	410·972
17⅞	56·156	250·947	23	72·256	415·476
18	56·548	254·469	23⅛	72·649	420·004
18⅛	56·941	258·016	23¼	73·042	424·557
18¼	57·334	261·587	23⅜	73·434	429·135
18⅜	57·726	265·182	23½	73·827	433·731
18½	58·119	268·803	23⅝	74·220	438·363
18⅝	58·512	272·447	23¾	74·613	443·014
18¾	58·905	276·117	23⅞	75·005	447·699
18⅞	59·297	279·811	24	75·398	452·390
19	59·690	283·529	24¼	76·183	461·864
19⅛	60·083	287·272	24½	76·969	471·436
19¼	60·475	291·039	24¾	77·754	481·106
19⅜	60·868	294·831	25	78·540	490·875
19½	61·261	298·648	25¼	79·325	500·741
19⅝	61·653	302·489	25½	80·110	510·706
19¾	62·046	306·355	25¾	80·896	520·769
19⅞	62·439	310·245	26	81·681	530·930
20	62·832	314·160	26¼	82·467	541·189
20⅛	63·224	318·099	26½	83·252	551·547
20¼	63·617	322·063	26¾	84·037	562·002
20⅜	64·010	326·051	27	84·823	572·556
20½	64·402	330·064	27¼	85·608	583·208
20⅝	64·795	334·101	27½	86·394	593·958
20¾	65·188	338·163	27¾	87·179	604·807
20⅞	65·580	342·250	28	87·964	615·753
21	65·973	346·361	28¼	88·750	626·798
21⅛	66·366	350·497	28½	89·535	637·941
21¼	66·759	354·657	28¾	90·321	649·182
21⅜	67·151	358·841	29	91·106	660·521
21½	67·544	363·051	29¼	91·891	671·958
21⅝	67·937	367·284	29½	92·677	683·494

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
29¾	93·462	695·128	40	125·664	1256·64
30	94·248	706·860	40¼	126·449	1272·39
30¼	95·033	718·690	40½	127·234	1288·25
30½	95·818	730·618	40¾	128·020	1304·20
30¾	96·604	742·644	41	128·805	1320·25
31	97·389	754·769	41¼	129·591	1336·40
31¼	98·175	766·992	41½	130·376	1352·65
31½	98·968	779·313	41¾	131·161	1369·00
31¾	99·745	791·732	42	131·947	1385·44
32	100·531	804·249	42¼	132·732	1401·98
32¼	101·316	816·865	42½	133·518	1418·62
32½	102·102	829·578	42¾	134·303	1435·36
32¾	102·887	842·390	43	135·088	1452·20
33	103·672	855·30	43¼	135·874	1469·13
33¼	104·458	868·30	43½	136·659	1486·17
33½	105·243	881·41	43¾	137·445	1503·30
33¾	106·029	894·61	44	138·230	1520·53
34	106·814	907·92	44¼	139·015	1537·86
34¼	107·599	921·32	44½	139·801	1555·28
34½	108·385	934·82	44¾	140·586	1572·81
34¾	109·170	948·41	45	141·372	1590·43
35	109·956	962·11	45¼	142·157	1608·15
35¼	110·741	975·90	45½	142·942	1625·97
35½	111·526	989·80	45¾	143·728	1643·89
35¾	112·312	1003·78	46	144·513	1661·90
36	113·097	1017·87	46¼	145·299	1680·01
36¼	113·883	1032·06	46½	146·084	1698·23
36½	114·668	1046·35	46¾	146·869	1716·54
36¾	115·453	1060·73	47	147·655	1734·94
37	116·239	1075·21	47¼	148·440	1753·45
37¼	117·024	1089·79	47½	149·226	1772·05
37½	117·810	1104·46	47¾	150·011	1790·76
37¾	118·595	1119·24	48	150·796	1809·56
38	119·380	1134·11	48¼	151·582	1828·46
38¼	120·166	1149·08	48½	152·367	1847·45
38½	120·951	1164·15	48¾	153·153	1866·55
38¾	121·737	1179·32	49	153·938	1885·74
39	122·522	1194·59	49¼	154·723	1905·03
39¼	123·307	1209·95	49½	155·509	1924·42
39½	124·093	1225·42	49¾	156·294	1943·91
39¾	124·878	1240·98	50	157·080	1963·50

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
70¾	222·268	3931·36	81	254·469	5153·00
71	223·053	3959·20	81¼	255·254	5184·84
71¼	223·839	3987·13	81½	256·040	5216·82
71½	224·624	4015·16	81¾	256·825	5248·84
71¾	225·409	4043·28	82	257·611	5281·02
72	226·195	4071·51	82¼	258·396	5313·28
72¼	226·980	4099·83	82½	259·182	5345·62
72½	227·766	4128·25	82¾	259·967	5378·04
72¾	228·551	4156·77	83	260·752	5410·62
73	229·336	4185·39	83¼	261·537	5443·24
73¼	230·122	4214·11	83½	262·323	5476·00
73½	230·907	4242·92	83¾	263·108	5508·84
73¾	231·693	4271·83	84	263·894	5541·78
74	232·478	4300·85	84¼	264·679	5574·80
74¼	233·263	4329·95	84½	265·465	5607·95
74½	234·049	4359·16	84¾	266·250	5641·16
74¾	234·834	4388·47	85	267·036	5674·51
75	235·620	4417·87	85¼	267·821	5707·92
75¼	236·405	4447·37	85½	268·606	5741·47
75½	237·190	4476·97	85¾	269·392	5775·09
75¾	237·976	4506·67	86	270·177	5808·81
76	238·761	4536·47	86¼	270·962	5842·60
76¼	239·547	4566·36	86½	271·748	5876·55
76½	240·332	4596·35	86¾	272·533	5910·52
76¾	241·117	4626·44	87	273·319	5944·69
77	241·903	4656·63	87¼	274·104	5978·88
77¼	242·688	4686·92	87½	274·890	6013·21
77½	243·474	4717·30	87¾	275·675	6047·60
77¾	244·259	4747·79	88	276·460	6082·13
78	245·044	4778·37	88¼	277·245	6116·72
78¼	245·830	4809·05	88½	278·031	6151·44
78½	246·615	4839·83	88¾	278·816	6186·20
78¾	247·401	4870·70	89	279·602	6221·15
79	248·186	4901·68	89¼	280·387	6256·12
79¼	248·971	4932·75	89½	281·173	6291·25
79½	249·757	4963·92	89¾	281·958	6326·44
79¾	250·542	4995·19	90	282·744	6361·74
80	251·328	5026·56	90¼	283·529	6399·12
80¼	252·113	5058·00	90½	284·314	6432·62
80½	252·898	5089·58	90¾	285·099	6468·16
80¾	253·683	5121·22	91	285·885	6503·89

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
50¼	157·865	1983·18	60½	190·066	2874·76
50½	158·650	2002·96	60¾	190·852	2898·56
50¾	159·436	2022·84	61	191·637	2922·47
51	160·221	2042·82	61¼	192·423	2946·47
51¼	161·007	2062·90	61½	193·208	2970·57
51½	161·792	2083·07	61¾	193·993	2994·77
51¾	162·577	2103·35	62	194·779	3019·07
52	163·363	2123·72	62¼	195·564	3043·47
52¼	164·148	2144·19	62½	196·350	3067·96
52½	164·934	2164·75	62¾	197·135	3092·56
52¾	165·719	2185·42	63	197·920	3117.25
53	166·504	2206·18	63¼	198·706	3142·04
53¼	167·290	2227·05	63½	199·491	3166·92
53½	168·075	2248·01	63¾	200·277	3191·91
53¾	168·861	2269·06	64	201·062	3216·99
54	169·646	2290·22	64¼	201·847	3242·17
54¼	170·431	2311·48	64½	202·633	3267·46
54½	171·217	2332·83	64¾	203·418	3292·83
54¾	172·002	2354·28	65	204·204	3318·31
55	172·788	2375·83	65¼	204·989	3343·88
55¼	173·573	2397·48	65½	205·774	3369·56
55½	174·358	2419·22	65¾	206·560	3395·33
55¾	175·144	2441·07	66	207·345	3421·20
56	175·929	2463·01	66¼	208·131	3447·16
56¼	176·715	2485·05	66½	208·916	3473·23
56½	177·500	2507·19	66¾	209·701	3499·39
56¾	178·285	2529·42	67	210·487	3525·66
57	179·071	2551·76	67¼	211·272	3552·01
57¼	179·856	2574·19	67½	212·058	3578·47
57½	180·642	2596·72	67¾	212·843	3605·03
57¾	181·427	2619·35	68	213·628	3631·68
58	182·212	2642·08	68¼	214·414	3658·44
58¼	182·998	2664·91	68½	215·199	3685·29
58½	183·783	2687·83	68¾	215·985	3712·24
58¾	184·569	2710·85	69	216·770	3739·28
59	185·354	2733·97	69¼	217·555	3766·43
59¼	186·139	2757·19	69½	218·341	3793·67
59½	186·925	2780·51	69¾	219·126	3821·02
59¾	187·710	2803·92	70	219·912	3848·46
60	188·496	2827·44	70¼	220·697	3875·99
60¼	189·281	2851·05	70½	221·482	3903·63

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
70¾	222·268	3931·36	81	254·469	5153·00
71	223·053	3959·20	81¼	255·254	5184·84
71¼	223·839	3987·13	81½	256·040	5216·82
71½	224·624	4015·16	81¾	256·825	5248·84
71¾	225·409	4043·28	82	257·611	5281·02
72	226·195	4071·51	82¼	258·396	5313·28
72¼	226·980	4099·83	82½	259·182	5345·62
72½	227·766	4128·25	82¾	259·967	5378·04
72¾	228·551	4156·77	83	260·752	5410·62
73	229·336	4185·39	83¼	261·537	5443·24
73¼	230·122	4214·11	83½	262·323	5476·00
73½	230·907	4242·92	83¾	263·108	5508·84
73¾	231·693	4271·83	84	263·894	5541·78
74	232·478	4300·85	84¼	264·679	5574·80
74¼	233·263	4329·95	84½	265·465	5607·95
74½	234·049	4359·16	84¾	266·250	5641·16
74¾	234·834	4388·47	85	267·036	5674·51
75	235·620	4417·87	85¼	267·821	5707·92
75¼	236·405	4447·37	85½	268·606	5741·47
75½	237·190	4476·97	85¾	269·392	5775·09
75¾	237·976	4506·67	86	270·177	5808·81
76	238·761	4536·47	86¼	270·962	5842·60
76¼	239·547	4566·36	86½	271·748	5876·55
76½	240·332	4596·35	86¾	272·533	5910·52
76¾	241·117	4626·44	87	273·319	5944·69
77	241·903	4656·63	87¼	274·104	5978·88
77¼	242·688	4686·92	87½	274·890	6013·21
77½	243·474	4717·30	87¾	275·675	6047·60
77¾	244·259	4747·79	88	276·460	6082·13
78	245·044	4778·37	88¼	277·245	6116·72
78¼	245·830	4809·05	88½	278·031	6151·44
78½	246·615	4839·83	88¾	278·816	6186·20
78¾	247·401	4870·70	89	279·602	6221·15
79	248·186	4901·68	89¼	280·387	6256·12
79¼	248·971	4932·75	89½	281·173	6291·25
79½	249·757	4963·92	89¾	281·958	6326·44
79¾	250·542	4995·19	90	282·744	6361·74
80	251·328	5026·56	90¼	283·529	6399·12
80¼	252·113	5058·00	90½	284·314	6432·62
80½	252·898	5089·58	90¾	285·099	6468·16
80¾	253·683	5121·22	91	285·885	6503·89

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
[illegible]	[illegible]	[illegible]	93¾	294·524	6882·92
[illegible]	[illegible]	[illegible]	94	295·310	6939·79
[illegible]	[illegible]	[illegible]	94¼	296·095	6976·72
[illegible]	[illegible]	[illegible]	94½	296·881	7013·81
[illegible]	[illegible]	[illegible]	94¾	297·666	7050·92
[illegible]	[illegible]	[illegible]	95	298·452	7088·23
[illegible]	[illegible]	[illegible]	95¼	299·237	7125·56
[illegible]	[illegible]	[illegible]	95½	300·022	7163·04
[illegible]	[illegible]	[illegible]	95¾	300·807	7200·56
[illegible]	[illegible]	[illegible]	96	301·593	7238·24

Table of Squares, Cubes, Square Roots, and Cube Roots.

Number.	Square.	Cube.	Square Root.	Cube Root.
1	1	1	1·0	1·0
2	4	8	1·41421	1·2599
3	9	27	1·73205	1·4423
4	16	64	2·0	1·5874
5	25	125	2·23607	1·7099
6	36	216	2·44949	1·8171
7	49	343	2·64575	1·9129
8	64	512	2·82843	2·0
9	81	729	3·0	2·0801
10	100	1000	3·16228	2·1544
11	121	1331	3·31663	2·2239
12	144	1728	3·46410	2·2894
13	169	2197	3·60555	2·3513
14	196	2744	3·74166	2·4101
15	225	3375	3·87298	2·4662
16	256	4096	4·0	2·5198
17	289	4913	4·12311	2·5713
18	324	5832	4·24264	2·6207
19	361	6859	4·35890	2·6684
20	400	8000	4·47214	2·7144

Number.	Square.	Cube.	Square Root.	Cube Root.
21	441	9261	4·58258	2·7589
22	484	10648	4·69042	2·8020
23	529	12167	4·79583	2·8439
24	576	13824	4·89898	2·8845
25	625	15625	5·0	2·9240
26	676	17576	5·09902	2·9625
27	729	19683	5·19615	3·0
28	784	21952	5·29150	3·0366
29	841	24389	5·38517	3·0723
30	900	27000	5·47723	3·1072
31	961	29791	5·56776	3·1414
32	1024	32768	5·65685	3·1748
33	1089	35937	5·74456	3·2075
34	1156	39304	5·83095	3·2396
35	1225	42875	5·91608	3·2711
36	1296	46656	6·0	3·3019
37	1369	50653	6·08276	3·3322
38	1444	54872	6·16441	3·3619
39	1521	59319	6·245	3·3912
40	1600	64000	6·32456	3·4199
41	1681	68921	6·40312	3·4482
42	1764	74088	6·48074	3·4760
43	1849	79507	6·55744	3·5034
44	1936	85184	6·63325	3·5303
45	2025	91125	6·70820	3·5569
46	2116	97336	6·78230	3·5830
47	2209	103823	6·85566	3·6088
48	2304	110592	6·92820	3·6342
49	2401	117649	7·0	3·6593
50	2500	125000	7·07107	3·6840
51	2601	132651	7·14143	3·7084
52	2704	140608	7·21110	3·7325
53	2809	148877	7·28011	3·7563
54	2916	157464	7·34847	3·7798
55	3025	166375	7·4162	3·8029
56	3136	175616	7·48332	3·8259
57	3249	185193	7·54983	3·8485
58	3364	195112	7·61577	3·8709
59	3481	205379	7·68115	3·8930
60	3600	216000	7·74597	3·9149
61	3721	226981	7·81025	3·9365
62	3844	238328	7·87401	3·9579

Number.	Square.	Cube.	Square Root.	Cube Root.
63	3969	250047	7·93725	3·9791
64	4096	262144	8·0	4·0
65	4225	274625	8·06226	4·0207
66	4356	287496	8·12404	4·0412
67	4489	300763	8·18535	4·0615
68	4624	314432	8·24621	4·0817
69	4761	328509	8·30662	4·1016
70	4900	343000	8·36660	4·1213
71	5041	357911	8·42615	4·1408
72	5184	373248	8·48528	4·1602
73	5329	389017	8·54400	4·1793
74	5476	405224	8·60233	4·1983
75	5625	421875	8·66025	4·2172
76	5776	438976	8·71779	4·2358
77	5929	456533	8·77496	4·2543
78	6084	474552	8·83176	4·2727
79	6241	493039	8·88819	4·2908
80	6400	512000	8·944	4·3089
81	6561	531441	9·0	4·3267
82	6724	551368	9·05589	4·3445
83	6889	571787	9·11043	4·3621
84	7056	592704	9·16515	4·3795
85	7225	614125	9·21955	4·3968
86	7396	636056	9·27362	4·4141
87	7569	658503	9·32738	4·4314
88	7744	681472	9·38083	4·4479
89	7921	704969	9·43398	4·4647
90	8100	729000	9·48683	4·4814
91	8281	753571	9·53939	4·4979
92	8464	778688	9·59166	4·5144
93	8649	804357	9·64365	4·5307
94	8836	830584	9·69536	4·5468
95	9025	857375	9·74679	4·5629
96	9216	884736	9·79796	4·5789
97	9409	912673	9·84886	4·5947
98	9604	941192	9·89949	4·6104
99	9801	970299	9·94987	4·6261
100	10000	1000000	10·0	4·6416

Table of the Weight of Cast-iron Balls.

Diam. in inches.	Weight in lbs.	Diam. in inches.	Weight in lbs.	Diam. in inches.	Weight in lbs.
2	1·10	6	29·72	10	137·71
2¼	1·57	6¼	33·62	10¼	148·28
2½	2·15	6½	37·80	10½	159·40
2¾	2·86	6¾	42·35	10¾	171·05
3	3·72	7	47·21	11	183·29
3¼	4·71	7¼	52·47	11¼	196·10
3½	5·80	7½	58·06	11½	209·43
3¾	7·26	7¾	64·09	11¾	223·40
4	8·81	8	70·49	12	237·94
4¼	10·57	8¼	77·32	12¼	253·13
4½	12·55	8½	84·56	12½	268·97
4¾	14·76	8¾	92·24	12¾	285·37
5	17·12	9	100·39	13	302·41
5¼	19·93	9¼	108·98	13¼	320·80
5½	22·91	9½	118·06	13½	338·81
5¾	26·18	9¾	127·63	13¾	357·93

Table of the Weight of Solid Cylinders in Cast Iron, One Foot long.

	Diameters in inches.								
	1	2	3	4	5	6	7	8	9
Weight in lbs.	2·4	9·9	21·9	39·0	61·0	89·0	120·0	156·0	198·0

Table of Decimal Equivalents. One Inch the Integer.

·96875 = $\frac{7}{8}$ and $\frac{3}{32}$		·46875 = $\frac{3}{8}$ and $\frac{3}{32}$	
·9375 = $\frac{7}{8}$,, $\frac{1}{16}$		·4375 = $\frac{3}{8}$,, $\frac{1}{16}$	
·90625 = $\frac{7}{8}$,, $\frac{1}{32}$		·40625 = $\frac{3}{8}$,, $\frac{1}{32}$	
·875 = $\frac{7}{8}$		·375 = $\frac{3}{8}$	
·84375 = $\frac{3}{4}$,, $\frac{3}{32}$		·34375 = $\frac{1}{4}$,, $\frac{3}{32}$	
·8125 = $\frac{3}{4}$,, $\frac{1}{16}$		·3125 = $\frac{1}{4}$,, $\frac{1}{16}$	
·78125 = $\frac{3}{4}$,, $\frac{1}{32}$		·28125 = $\frac{1}{4}$,, $\frac{1}{32}$	
·75 = $\frac{3}{4}$		·25 = $\frac{1}{4}$	
·71875 = $\frac{5}{8}$,, $\frac{3}{32}$		·21875 = $\frac{1}{8}$,, $\frac{3}{32}$	
·6875 = $\frac{5}{8}$,, $\frac{1}{16}$		·1875 = $\frac{1}{8}$,, $\frac{1}{16}$	
·65625 = $\frac{5}{8}$,, $\frac{1}{32}$		·15625 = $\frac{1}{8}$,, $\frac{1}{32}$	
·625 = $\frac{5}{8}$		·125 = $\frac{1}{8}$	
·59375 = $\frac{1}{2}$,, $\frac{3}{32}$		·09375 = $\frac{3}{32}$	
·5625 = $\frac{1}{2}$,, $\frac{1}{16}$		·0625 = $\frac{1}{16}$	
·53125 = $\frac{1}{2}$,, $\frac{1}{32}$		·03125 = $\frac{1}{32}$	
·5 = $\frac{1}{2}$			

Table of Decimal Equivalents. One Foot the Integer.

·9166 = 11 inches.	·1666 = 2 inches.
·6338 = 10 ,,	·0833 = 1 inch.
·75 = 9 ,,	·07291 = $\frac{7}{8}$ of inch.
·6666 = 8 ,,	·0625 = $\frac{3}{4}$,,
·5833 = 7 ,,	·05208 = $\frac{5}{8}$,,
·5 = 6 ,,	·04166 = $\frac{1}{2}$,,
·4166 = 5 ,,	·03125 = $\frac{3}{8}$,,
·3333 = 4 ,,	·02083 = $\frac{1}{4}$,,
·25 = 3 ,,	·01041 = $\frac{1}{8}$,,

TABLE OF DIMENSIONS FOR PIPE FLANGES AND SOCKETS.

Diameter of Pipe.	Diameter of Flange.	Thickness of Flange.	No. of Bolts.	Bore of Socket.	Depth of Socket.
Inches.	Inches.	Inches.		Inches.	Inches.
2	6 to 6½	½	4	3¼	2¾
3	7½ ,, 8	⅝	4	4½	3
4	8½ ,, 9	¾	4	5¾	3½
5	10 ,, 10½	¾	6	6¾	4
6	11 ,, 11½	¾	6	7¾	4½
7	12 ,, 13	⅞	6	8¾	4½
8	13 ,, 14	⅞	6	9¾	4½
9	14 ,, 15	⅞	6	11	4½
10	16	1	6	12	4½
11	17	1	6	13	4½
12	18	1	6	14	4½

The above dimensions are good, but not arbitrary. The usages of manufacturers differ, some making their flanges smaller, others larger than these. Obviously, too, the proportions and the number of bolts and flanges will vary with the strains the pipes have to bear.

Table of Pitches, Pitch Diameters, and Number of Teeth of Wheels.

No. of Teeth.	Pitch of the Teeth in Inches. — Diameter of the Pitch Circle in Feet and Inches.																											
	1 inch.		1⅛ inch.		1¼ inch.		1⅜ inch.		1½ inch.		1⅝ inch.		1¾ inch.		1⅞ inch.		2 inch.		2⅛ inch.		2¼ inch.		2½ inch.		2¾ inch.		3 inch.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
10	0	3¼	0	3⅝	0	4	0	4½	0	4⅞	0	5¼	0	5⅝	0	6	0	6½	0	6⅞	0	7¼	0	8	0	8⅞	0	9⅝
11	0	3½	0	4	0	4⅜	0	5	0	5⅜	0	5¾	0	6¼	0	6⅝	0	7	0	7½	0	7⅞	0	8¾	0	9¾	0	10⅝
12	0	3⅞	0	4⅜	0	4⅞	0	5⅜	0	5⅞	0	6⅜	0	6¾	0	7⅛	0	7⅝	0	8⅛	0	8⅝	0	9⅝	0	10⅝	0	11½
13	0	4⅛	0	4¾	0	5¼	0	5¾	0	6¼	0	6⅞	0	7⅜	0	7⅞	0	8⅜	0	8⅞	0	9⅜	0	10⅜	0	11½	1	0½
14	0	4½	0	5	0	5⅝	0	6¼	0	6¾	0	7⅜	0	7⅞	0	8½	0	9	0	9½	0	10	0	11¼	1	0⅜	1	1½
15	0	4⅞	0	5⅜	0	6	0	6⅝	0	7¼	0	7⅞	0	8½	0	9	0	9⅝	0	10¼	0	10¾	1	0	1	1¼	1	2⅜
16	0	5⅛	0	5¾	0	6⅜	0	7	0	7⅝	0	8⅜	0	9	0	9⅝	0	10¼	0	10⅞	0	11½	1	0¾	1	2	1	3⅜
17	0	5½	0	6⅛	0	6¾	0	7½	0	8¼	0	8⅞	0	9⅝	0	10¼	0	10⅞	0	11½	1	0¼	1	1½	1	2⅞	1	4¼
18	0	5¾	0	6½	0	7⅛	0	8	0	8⅝	0	9⅜	0	10	0	10¾	0	11½	1	0¼	1	0⅞	1	2⅜	1	3¾	1	5¼
19	0	6	0	6⅞	0	7½	0	8⅜	0	9⅛	0	9⅞	0	10⅝	0	11⅜	1	0⅛	1	0⅞	1	1⅝	1	3⅛	1	4⅝	1	6¼
20	0	6⅜	0	7⅛	0	8	0	8⅞	0	9⅝	0	10⅜	0	11¼	1	0	1	0¾	1	1½	1	2⅜	1	4	1	5½	1	7⅛
21	0	6¾	0	7½	0	8⅜	0	9¼	0	10	0	11	0	11¾	1	0½	1	1½	1	2¼	1	3	1	4¾	1	6⅜	1	8⅛
22	0	7	0	7⅞	0	8¾	0	9⅝	0	10⅝	0	11½	1	0⅜	1	1⅛	1	2	1	2⅞	1	3¾	1	5½	1	7¼	1	9
23	0	7⅜	0	8¼	0	9⅛	0	10	0	11	1	0	1	0⅞	1	1¾	1	2⅝	1	3½	1	4½	1	6⅜	1	8	1	10
24	0	7⅝	0	8⅝	0	9½	0	10½	0	11½	1	0½	1	1½	1	2⅜	1	3⅜	1	4¼	1	5¼	1	7⅛	1	9	1	10⅞
25	0	8	0	9	0	10	0	11	1	0	1	1	1	2	1	2⅞	1	3⅞	1	4⅞	1	6	1	8	1	9⅞	1	11⅞
26	0	8¼	0	9¼	0	10⅜	0	11½	1	0½	1	1½	1	2½	1	3½	1	4½	1	5½	1	6⅝	1	8¾	1	10¾	2	0⅞
27	0	8⅝	0	9⅝	0	10¾	0	11⅞	1	1	1	2	1	3	1	4⅛	1	5¼	1	6¼	1	7⅜	1	9½	1	11⅝	2	1¾

28	0	9	0	10	0	11¼	1	0¼	1	1¼	1	2½	1	3⅝	1	4⅝	1	5¾	1	6⅞	1	8	1	10¼	2	0½	2	2¾
29	0	9¼	0	10⅜	0	11⅝	1	0¾	1	1⅞	1	3	1	4⅛	1	5⅜	1	6½	1	7⅝	1	8¾	1	11⅛	2	1⅜	2	3¾
30	0	9½	0	10¾	1	0	1	1⅛	1	2⅜	1	3½	1	4½	1	6	1	7⅛	1	8¼	1	9½	2	0	2	2¼	2	4⅝
31	0	9⅞	0	11⅛	1	0⅜	1	1⅝	1	2⅞	1	4	1	5⅜	1	6½	1	7¾	1	9	1	10¼	2	0¾	2	3⅛	2	5⅝
32	0	10¼	0	11½	1	0¾	1	2	1	3⅜	1	4⅝	1	5⅞	1	7⅛	1	8⅜	1	9⅝	1	11	2	1½	2	4	2	6½
33	0	10½	0	11⅞	1	1⅛	1	2½	1	3¾	1	5⅛	1	6½	1	7¾	1	9	1	10⅜	1	11⅝	2	2¼	2	4⅞	2	7½
34	0	10⅞	1	0⅛	1	1⅝	1	3	1	4¼	1	5⅝	1	7	1	8⅜	1	9⅝	1	11	2	0⅜	2	3	2	5¾	2	8½
35	0	11⅛	1	0⅝	1	2	1	3⅜	1	4¾	1	6⅛	1	7½	1	9	1	10⅛	1	11¾	2	1	2	3⅞	2	6⅝	2	9½
36	0	11½	1	1	1	2⅜	1	3¾	1	5¼	1	6⅝	1	8	1	9½	1	10⅞	2	0⅜	2	2	2	4⅝	2	7½	2	10⅜
37	0	11¾	1	1¼	1	2¾	1	4¼	1	5⅝	1	7¼	1	8⅝	1	10	1	11½	2	1	2	2½	2	5½	2	8⅜	2	11⅜
38	1	0⅛	1	1⅝	1	3¼	1	4⅝	1	6¼	1	7⅝	1	9¼	1	10¾	2	0¼	2	1¾	2	3¼	2	6¼	2	9¼	3	0¼
39	1	0⅜	1	2	1	3½	1	5	1	6⅝	1	8¼	1	9¾	1	11⅜	2	0⅞	2	2⅜	2	4	2	7	2	10⅛	3	1¼
40	1	0¾	1	2⅜	1	4	1	5½	1	7⅜	1	8¾	1	10⅜	1	11⅞	2	1½	2	3	2	4⅝	2	7⅞	2	10¾	3	2¼
41	1	1	1	2¾	1	4⅜	1	6	1	7⅝	1	9¼	1	10⅞	2	0½	2	2⅛	2	3¾	2	5⅜	2	8⅝	2	11⅞	3	3⅛
42	1	1⅜	1	3	1	4¾	1	6⅜	1	8	1	9¾	1	11½	2	1	2	2¾	2	4½	2	6	2	9⅜	3	0¾	3	4⅛
43	1	1⅝	1	3½	1	5⅛	1	6⅞	1	8⅝	1	10¼	2	0	2	1⅝	2	3⅜	2	5	2	6¾	2	10¼	3	1⅝	3	5
44	1	2	1	3¾	1	5⅝	1	7¼	1	9	1	10¾	2	0½	2	2¼	2	4	2	5¾	2	7½	2	11	3	2½	3	6
45	1	2⅜	1	4⅛	1	6	1	7¾	1	9½	1	11⅜	2	1	2	2⅞	2	4⅝	2	6½	2	8¼	2	11¾	3	3⅜	3	7
46	1	2⅝	1	4½	1	6⅜	1	8⅛	1	10	1	11⅞	2	1⅝	2	3½	2	5¼	2	7⅛	2	9	3	0⅝	3	4¼	3	7⅞
47	1	2⅞	1	4⅞	1	6¾	1	8⅝	1	10½	2	0⅜	2	1⅞	2	4	2	6	2	7⅞	2	9⅝	3	1½	3	5⅛	3	8⅞
48	1	3¼	1	5¼	1	7⅛	1	9	1	11	2	0⅞	2	2¾	2	4⅝	2	6½	2	8½	2	10⅜	3	2¼	3	6	3	9⅞
49	1	3½	1	5⅝	1	7½	1	9½	1	11½	2	1⅜	2	3⅜	2	5¼	2	7¼	2	9⅛	2	11	3	3	3	6⅞	3	10⅞
50	1	3⅞	1	6	1	8	1	9⅞	2	0	2	1⅞	2	3⅞	2	5⅞	2	7⅞	2	9¾	2	11¾	3	3¾	3	7¾	3	11¾
51	1	4¼	1	6¼	1	8⅜	1	10⅜	2	0⅜	2	2⅜	2	4½	2	6½	2	8½	2	10½	3	0½	3	4½	3	8⅝	4	¾
52	1	4½	1	6⅝	1	8¾	1	10¾	2	0⅞	2	2⅞	2	4⅞	2	7⅛	2	9⅛	2	11⅛	3	1¼	3	5⅜	3	9½	4	1⅝
53	1	4⅞	1	6⅞	1	9⅛	1	11¼	2	1¼	2	3⅜	2	5⅜	2	7⅝	2	9¾	2	11⅞	3	2	3	6¼	3	10½	4	2⅝
54	1	5⅛	1	7⅜	1	9½	1	11⅜	2	1¾	2	3⅞	2	6	2	8¼	2	10⅜	3	0½	3	2⅝	3	7	3	11	4	3½

No. of Teeth.	Pitch of the Teeth in Inches. Diameter of the Pitch Circle—*continued.* 1 inch. ft.	1 inch. in.	1⅛ inch. ft.	1⅛ inch. in.	1¼ inch. ft.	1¼ inch. in.	1⅜ inch. ft.	1⅜ inch. in.	1½ inch. ft.	1½ inch. in.	1⅝ inch. ft.	1⅝ inch. in.	1¾ inch. ft.	1¾ inch. in.	1⅞ inch. ft.	1⅞ inch. in.	2 inch. ft.	2 inch. in.	2⅛ inch. ft.	2⅛ inch. in.	2¼ inch. ft.	2¼ inch. in.	2½ inch. ft.	2½ inch. in.	2¾ inch. ft.	2¾ inch. in.	3 inch. ft.	3 inch. in.
55	1	5½	1	7¾	1	9⅞	2	0	2	2¼	2	4½	2	6⅝	2	8⅞	2	11	3	1¼	3	3½	3	7¾	4	0⅛	4	4½
56	1	5⅞	1	8⅛	1	10¼	2	0½	2	2¾	2	4⅞	2	7⅛	2	9⅜	2	11⅝	3	1⅞	3	4⅛	3	8½	4	1	4	5½
57	1	6⅛	1	8½	1	10⅝	2	0⅞	2	3¼	2	5¼	2	7¾	2	10	3	0¼	3	2½	3	4⅞	3	9⅜	4	1⅞	4	6⅜
58	1	6½	1	8¾	1	11	2	1⅜	2	3⅝	2	6	2	8¼	2	10⅝	3	0⅞	3	3¼	3	5½	3	10⅛	4	2¾	4	7⅜
59	1	6¾	1	9⅛	1	11½	2	1⅞	2	4⅛	2	6½	2	8⅞	2	11¼	3	1½	3	4	3	6¼	3	11⅛	4	3⅝	4	8⅜
60	1	7⅛	1	9⅜	1	11⅞	2	2¼	2	4⅝	2	7	2	9⅜	2	11¾	3	2¼	3	4⅝	3	7	3	11¾	4	4½	4	9¼
61	1	7½	1	9⅞	2	0¼	2	2¾	2	5¼	2	7½	2	10	3	0⅜	3	2⅞	3	5¼	3	7¾	4	0½	4	5⅜	4	10¼
62	1	7¾	1	10¼	2	0⅝	2	3⅛	2	5⅝	2	8	2	10½	3	1	3	3½	3	6	3	8½	4	1⅜	4	6¼	4	11¼
63	1	8	1	10½	2	1	2	3½	2	6	2	8⅝	2	11	3	1⅝	3	4⅛	3	6⅝	3	9⅛	4	2⅛	4	7⅛	5	0⅛
64	1	8⅜	1	10⅞	2	1½	2	4	2	6½	2	9⅛	2	11⅝	3	2¼	3	4¾	3	7¼	3	9⅞	4	3	4	8	5	1⅛
65	1	8⅝	1	11¼	2	1⅞	2	4½	2	7	2	9⅝	3	0¼	3	2⅞	3	5⅜	3	8	3	10½	4	3¾	4	8⅞	5	2
66	1	9	1	11⅝	2	2¼	2	4⅞	2	7½	2	10⅛	3	0⅞	3	3⅜	3	6	3	8⅝	3	11¼	4	4½	4	9¾	5	3
67	1	9⅜	2	0	2	2⅝	2	5¼	2	8	2	10⅝	3	1⅜	3	4	3	6½	3	9⅜	4	0	4	5⅜	4	10⅝	5	4
68	1	9⅝	2	0⅜	2	3	2	5¾	2	8½	2	11⅛	3	1¾	3	4⅝	3	7¼	3	10	4	0¾	4	6⅛	4	11½	5	5
69	1	9⅞	2	0¾	2	3½	2	6¼	2	8⅞	2	11¾	3	2⅜	3	5⅛	3	7⅞	3	10⅝	4	1½	4	7	5	0⅜	5	6
70	1	10¼	2	1	2	3⅞	2	6⅝	2	9⅜	3	0¼	3	3	3	5¾	3	8½	3	11⅜	4	2⅛	4	7¾	5	1¼	5	6⅞
71	1	10⅝	2	1½	2	4¼	2	7	2	9⅞	3	0¾	3	3½	3	6⅜	3	9¼	4	0	4	2⅞	4	8½	5	2⅛	5	7¾
72	1	10⅞	2	1¾	2	4⅝	2	7½	2	10⅜	3	1¼	3	4⅛	3	6¾	3	9⅞	4	0¾	4	3½	4	9¼	5	3	5	8¾
73	1	11¼	2	2⅛	2	5	2	8	2	10⅞	3	1¾	3	4⅝	3	7½	3	10½	4	1⅜	4	4¼	4	10	5	3⅞	5	9¾
74	1	11½	2	2½	2	5½	2	8⅜	2	11⅜	3	2¼	3	5¼	3	7⅞	3	11⅛	4	2	4	5	4	10⅞	5	4¾	5	10⅝

75	1 11⅞	2 2⅞	2 5⅞	2 8⅞	2 11⅞	3 2¾	3 5¾	3 8¾	3 11¾	4 2¾	4 5¾	4 11¾	5 5⅜	5 11⅝
76	2 0⅛	2 3¼	2 6¼	2 9¼	3 0¼	3 3¼	3 6⅜	3 9⅜	4 0⅜	4 3½	4 6½	5 0½	5 6½	6 0½
77	2 0½	2 3½	2 6⅝	2 9¾	3 0¾	3 3⅞	3 6⅞	3 9⅞	4 1	4 4	4 7⅛	5 1¼	5 7⅜	6 1½
78	2 0⅞	2 3⅞	2 7	2 10⅛	3 1½	3 4⅜	3 7½	3 10½	4 1⅝	4 4¾	4 7⅞	5 2	5 8¼	6 2½
79	2 1⅛	2 4⅛	2 7⅜	2 10½	3 1¾	3 4⅞	3 8	3 11⅛	4 2¼	4 5½	4 8½	5 2⅞	5 9⅛	6 3½
80	2 1½	2 4⅝	2 7¾	2 11	3 2¼	3 5⅜	3 8½	3 11¾	4 3	4 6⅛	4 9¼	5 3⅝	5 10	6 4⅜
81	2 1¾	2 5	2 8¼	2 11½	3 2⅝	3 5⅞	3 9⅛	4 0⅜	4 3½	4 6⅞	4 10	5 4½	5 10⅞	6 5⅜
82	2 2⅛	2 5⅜	2 8⅝	2 11⅞	3 3⅛	3 6⅜	3 9⅝	4 0⅞	4 4¼	4 7½	4 10¾	5 5¼	5 11¾	6 6⅜
83	2 2½	2 5¾	2 9	3 0⅜	3 3⅝	3 6⅞	3 10¼	4 1½	4 4⅞	4 8⅛	4 11½	5 6	6 0⅝	6 7¼
84	2 2¾	2 6	2 9⅜	3 0¾	3 4	3 7½	3 10¾	4 2⅛	4 5½	4 8⅞	5 0⅛	5 6⅞	6 1½	6 8⅛
85	2 3	2 6⅜	2 9¾	3 1¼	3 4½	3 7⅞	3 11¼	4 2¾	4 6⅛	4 9½	5 0⅞	5 7⅝	6 2⅜	6 9⅛
86	2 3⅜	2 6¾	2 10¼	3 1⅝	3 5¼	3 8½	3 11⅞	4 3¼	4 6¾	4 10⅛	5 1⅝	5 8½	6 3¼	6 10½
87	2 3⅝	2 7⅛	2 10⅝	3 2	3 5½	3 9	4 0½	4 3⅞	4 7⅜	4 10⅞	5 2¼	5 9¼	6 4⅛	6 11
88	2 4	2 7½	2 11	3 2½	3 6	3 9½	4 1	4 4½	4 8	4 11½	5 3	5 10	6 5	7 0
89	2 4⅜	2 7⅞	2 11⅜	3 2⅞	3 6½	3 10	4 1½	4 5⅛	4 8⅝	5 0¼	5 3¼	5 10¾	6 5⅞	7 1
90	2 4⅝	2 8¼	2 11¾	3 3¼	3 7	3 10½	4 2⅛	4 5¾	4 9¼	5 0⅞	5 4¼	5 11⅝	6 6¾	7 2
91	2 4⅞	2 8½	3 0¼	3 3⅞	3 7½	3 11	4 2¾	4 6¼	4 9⅞	5 1½	5 5⅛	6 0⅜	6 7⅝	7 2⅞
92	2 5¼	2 8⅞	3 0⅝	3 4¼	3 7⅞	3 11⅝	4 3¼	4 7	4 10½	5 2⅛	5 5⅞	6 1	6 8½	7 3⅞
93	2 5⅝	2 9¼	3 1	3 4¾	3 8⅜	4 0⅛	4 3⅞	4 7½	4 11¼	5 2⅞	5 6⅝	6 2	6 9⅜	7 4⅞
94	2 5⅞	2 9⅝	3 1⅜	3 5⅛	3 8⅞	4 0⅝	4 4⅜	4 8⅛	4 11¾	5 3½	5 7⅜	6 2¾	6 10¼	7 5¾
95	2 6¼	2 10	3 1¾	3 5½	3 9⅜	4 1⅛	4 4⅞	4 8¾	5 0½	5 4¼	5 8	6 3½	6 11⅛	7 6¾
96	2 6½	2 10⅜	3 2⅛	3 6	3 9¾	4 1⅝	4 5½	4 9⅜	5 1⅛	5 5	5 8¾	6 4⅜	7 0	7 7⅝
97	2 6⅞	2 10¾	3 2⅝	3 6½	3 10¼	4 2⅛	4 6	4 10	5 1¾	5 5⅝	5 9½	6 5¼	7 0⅞	7 8⅝
98	2 7⅛	2 11	3 3	3 6⅞	3 10¾	4 2⅝	4 6½	4 10½	5 2⅜	5 6¼	5 10⅛	6 6	7 1¾	7 9½
99	2 7½	2 11⅜	3 3⅜	3 7⅜	3 11¼	4 3¼	4 7⅛	4 11	5 3	5 7	5 11	6 6¾	7 2⅝	7 10½
100	2 7⅞	2 11⅞	3 3¾	3 7¾	3 11¾	4 3¾	4 7¾	4 11⅝	5 3⅝	5 7⅝	5 11⅝	6 7½	7 3⅝	7 11½

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THE END.

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