THE ART

OF

PATTERN-MAKING.

A COMPREHENSIVE TREATISE.

NUMEROUS EXAMPLES OF ALL KINDS OF PATTERN WORK FOR GREEN-SAND, DRY-SAND, AND LOAM MOULDING. PATTERN WORK FOR MARINE ENGINES AND SCREW PROPELLERS. ALSO USEFUL INFORMATION AND RULES FOR THE PRACTICAL USE OF PATTERN-MAKERS AND OTHERS.

BY

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Profusely Illustrated.

FIRST EDITION.

FIRST THOUSAND.

NEW YORK:
JOHN WILEY & SONS.
LONDON: CHAPMAN & HALL, LIMITED.
1903.

ROBERT DRUMMOND, PRINTER, NEW YORK.

PREFACE.

THE author's extensive experience in connection with pattern-making in nearly all of its variations impressed him with the belief that great benefit would be derived by many members of the craft by acquiring a more general knowledge of the business. No individual can have had the experience of many. The acquisition, then, of the knowledge of others must be gained through lectures or literature. The literature pertaining to pattern-making is by no means as extensive as the importance of the business warrants. There are many pattern-makers competent to treat the subject in a satisfactory manner, but have been deterred by the amount of time and labor necessary to do the subject justice.

The subjects chosen for illustration herein are chiefly those with which the author has had personal experience and were originally written for publication in "Machinery." He also records the experience of others in pattern-making; these examples have been selected chiefly from the correspondence of the "American Machinist." He has embodied whatever in his opinion would be of interest to the pattern-making fraternity.

Providing for the interior of castings, or core-box work, is correctly regarded as the most intricate and important part of pattern-making. Amongst the subjects several excellent examples of core-box work will be found.

Screw propellers are a special feature, and the examples given are thoroughly elucidated.

The author has always entertained a deep interest in pattern-making owing to its intricacy, the skill and intelligence required for its execution. In presenting this volume to its readers he hopes and believes it will be found a useful and desirable acquisition to the literature of pattern-making.

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THE ART OF PATTERN-MAKING.

I.

INTRODUCTION.

THE art of pattern-making comprises the modeling of objects that are intended to be cast of metals. Its origin is contemporaneous with that of the casting of bronze, and, like that of the latter, the period of its inception is lost in the oblivion of remote ages.

The first patterns were probably made of clay or of similar material, and were models of those rude bronze castings that have been found in ancient ruins. At a later period wax was employed for patterns which represented the more artistic bronze articles. In both these methods the models were usually destroyed in the process of moulding, and their consequent disappearance, in conjunction with the then existent limited knowledge of bronze founding, made the castings rare and valuable.

In the ancient wax process the modeling was done directly in the wax. When the object was large a core representing the interior form of the object was made of the same materials that formed the mould. Over this the wax was modeled and the mould was built around the model or pattern thus formed. In building the mould, inlets or gates through which the metal entered, and vents through which the gases escaped from the mould, were provided; these were also represented in wax. When the mould was heated in the process of baking, the wax melted and escaped through outlets provided for the purpose during the construction of the mould.

Wax is still used for patterns, although chiefly for ornamental work. In the modern process the modeling is done in clay, and a plaster mould made of the object thus modeled. The wax model is then produced by filling the plaster mould with molten wax. Plaster patterns are also used to a large extent in ornamental work. The process of producing them is similar to that of making wax patterns.

For many kinds of patterns plaster is a convenient material. It will readily take impressions with fidelity, its durability is such that it will withstand repeated use, and it is sufficiently cohesive to allow of a pattern being made in sections for convenience in moulding.

As the various arts requiring castings advanced and demanded larger and more complicated castings, the art of founding progressed with it. To meet this created demand it became necessary to produce larger and more complicated as well as more durable patterns.

Wood, then, of all materials, has been found to possess the qualities which are requisite in the construction of large and intricate patterns at moderate expense. Of the various kinds of wood suitable for pattern work, clear, dry white pine stands preeminent. Its abundance and cheapness, the ease with which it can be worked, combined with its constancy in retaining its form, has induced its employment for pattern work to a greater extent than all other materials combined. The kind of pine that grows in the neighborhood of the Great Lakes is the best. It is better without knots or sap, although a small knot or a little sap occasionally is not objectionable, especially for large patterns, provided the wood is thoroughly seasoned and dry, for this latter quality is of the first importance.

The shrinkage of white pine across the grain is well understood. It has been asserted that it will also shrink with the grain lengthwise, and under certain conditions this is possible to a small extent when the wood is of curly or cross-grained nature. A case of apparent shrinkage in length of white pine was related to the writer by a reliable person. In making a pattern he joined together two pieces of white pine and then planed off their ends, thus insuring their being of the same length. Subsequently, after the pattern had been used for moulding and had been stored in the pattern loft for some time, it was noticed that the two pieces were of unequal lengths. From the nature of the construction of the pattern and the position of the two pieces in it, the opinion was formed that the shorter piece had shrunk in length. The resistance that soft, white pine offers to compression is not very great. If a piece of this wood, of cross-section small in comparison to its length, is left standing on end a sufficient space of time, it is possible for it to decrease in length owing to its small power of withstanding compression, and thus create the belief that shrinkage was the cause of the change. For all practical purposes it may be said that soft, straight-grained white pine will not change its length by shrinkage.

When patterns are to be subjected to rough usage, or are to be used for many castings, harder woods, such as baywood, cherry, ash, maple, etc., are selected. The first-named of these possesses some of the qualities of white pine, in that it is easily worked and will hold its shape well; but it is the most expensive of the woods used. Of late years redwood has been largely employed in making patterns, but, although somewhat cheaper, it does not work as freely as white pine. Except for large and plain patterns, where the cost of material amounts to a large proportion of the entire expense of construction, the use of redwood for pattern work is of doubtful economy.

Metal patterns are also largely employed, but of course the original must have been made of wood or other material, and the metal pattern produced by process of founding.

Green-sand moulding is practiced to a greater extent than other methods, because it is the cheapest for producing castings, especially for small work that is to be much duplicated. In this the moulding is done in a suitable sand, moistened sufficiently to make it adhere together. Patterns for green-sand moulding are models of the object to be cast, and are made in such a manner that they may be readily withdrawn from the sand without mutilating the mould. To enable this to be accomplished the pattern is made in two or more sections, as the case necessitates, and so joined together as to allow the different parts to be withdrawn separately and in a manner depending on the form and position of the part. Core-prints are provided where necessary to locate and support the cores. Cores are bodies of prepared sand, baked. Their exterior form corresponds to an interior part of a casting, or to undercuts on its exterior that will prevent a model of it being withdrawn from the sand. In such a case the pattern is provided with core-prints which abolish the undercuts and leave impressions into which cores are inserted to supply the part or parts of the mould made vacant by the core-prints.

Dry-sand moulding is next in importance. In this method the moulding is done in sand mixed with materials that will cause it, after being baked in an oven, to adhere firmly together and withstand greater pressure without distortion than with green sand. Another advantage the dry-sand method possesses is that the mould may be "cheeked," as foundrymen say; that is, it may be divided into a number of parts and those parts lifted away to relieve undercuts and similar places in the patterns. Statuary is moulded in this manner.

Patterns for dry-sand moulding are constructed and finished in a similar manner to those for green sand, except that they can often be made with fewer pieces when the mould is to be "cheeked" and drawbacks employed.

Loam moulding is used for the larger and heavier castings. In this method the moulding is not done in a flask, as in the case of the two previously described methods, but is built up of brickwork, strengthened by rods and plates where necessary. The moulding material is a mixture of sand and other materials of about the consistency of mortar. It is worked into the mould between the pattern and brickwork. By this method the mould can be made into any number of necessary sections, which can be disjointed, thus relieving the pattern and allowing its withdrawal. When the sections are assembled in a pit and clamped together with sand firmly rammed around the mould the latter is prepared for the metal.

In constructing a pattern to be moulded in loam it is advisable to use wood sparingly, and where it is used provision should be made for its swelling, which it will do by absorbing moisture from the loam. A strike or sweep used in loam moulding is a flat piece of board with the edge so shaped as to conform to the profile of a part of the desired casting by revolving it on a spindle or moving it along guides, as the case requires. The required part of the mould can be formed without necessitating the pattern being worked out for it. A pattern to be moulded in loam is often but a skeleton of woodwork, some parts of it representing corresponding parts of the intended casting and other parts forming guides for sweeps. For instance, the mould for a plain cylinder may be formed altogether with sweeps by securing them to a spindle and revolving them while building up the mould.

Wooden patterns are usually finished with a coating of shellac dissolved in alcohol. This method is quick, furnishing a smooth surface, and provides protection against dampness when the pattern does not remain in the mould very long, as generally is the case with green-sand moulding. But when the pattern remains in the mould for a length of time, especially in a loam mould, which is very wet, shellac does not afford a very good protection against the absorption of moisture by the pattern, and swelling is then the result. Painting the pattern is the alternative in this case, but it is seldom practiced in this country, in consequence of its inconvenience. Thoroughly oiling the pattern previously to its being placed in a loam mould is the usual practice.

All metals in passing from the liquid to the solid state suffer expansion when in the plastic condition. It is this feature in the transition that enables metals to take and retain the impressions of moulds with such fidelity. In cooling from the plastic condition to the solid state metals contract; the amount of this contraction to normal temperature will vary for the various kinds of metals. Patterns have therefore to be made larger than the intended casting by this amount, and here occurs the necessity on the part of the pattern-maker for the use of discreet judgment based upon extended experience in order to obtain the best possible results, because different kinds of varying mixtures of iron as well as that of alloys will contract with varying amounts. Moreover, the varying proportions of castings when made of the same material will vary in their amount of contraction. Thus an extended and plain casting will contract differently from one of more compact form, though both may be of equal weight and cast at the same time and of the same material. It is necessary also to make an allowance for the parts of a casting that are to be finished, taking into consideration the liability of imperfection in the form of the casting.

All woods contain moisture to some extent. Wood kept for several years in a dry place will contain 15 or 20 per cent. of water. Wood that has been thoroughly kiln-dried will, when exposed to the air under ordinary circumstances, absorb 5 per cent. of moisture in the first three days, and will continue to absorb until it approximates 15 per cent. of water. Wood, however dry, is subject to change; it will swell or shrink according to the humidity of the atmosphere or the hygrometric conditions under which it is placed. These circumstances must be taken into consideration when a pattern is about to be constructed, and the material so manipulated that its swelling and shrinking will counteract each other in order that the pattern may retain its form and dimensions as nearly as possible.

There is another peculiarity of wood—its tendency to warp in one direction, the cause of which needs to be considered when a structure is to be built up with pieces of wood of various shapes and dimensions.

When a tree is sawn across it is observed apparently to be made up of a number of annular rings. One ring is reckoned for each year in the age of the tree. These rings are composed of numerous minute tubes known as capillary tubes. The sap which gives life and growth to the tree is absorbed by its roots from the soil through which they run. This sap is conveyed through the capillary tubes or veins of the tree by a mysterious force known as capillary attraction. When the capillary tubes are deprived of moisture they contract in diameter and consequently the system which they compose becomes smaller.

Fig. 1 illustrates a section of a tree with the capillary tubes somewhat exaggerated. If such a piece is cut at a season of the year when the tubes contain sap, it will split in the course of drying, as shown by Fig. 2, because the outside tubes dry out first and in shrinking the tenacity of the wood is not sufficient to overcome the resistance to compression offered by the wood within, which has not shrunk so much, and consequently as the shrinkage occurs with great force the outer wood is pulled apart. To prevent this tendency to split, a hole is often bored through the center with the grain; this enables the

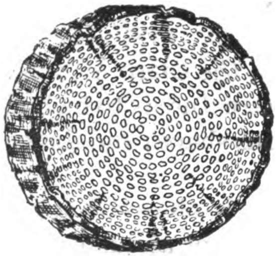


FIG. 1.

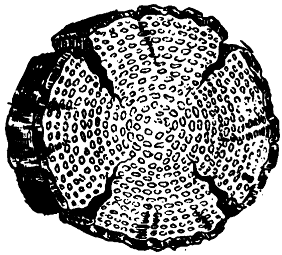


FIG. 2.

wood to dry and shrink from the inside as well as from the periphery. Fig. 3 shows the section cut with the grain into three parts, and Fig. 4 shows it cut into six parts; they also show the direction in

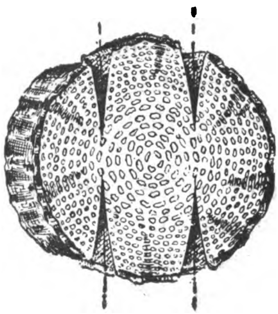


FIG. 3.

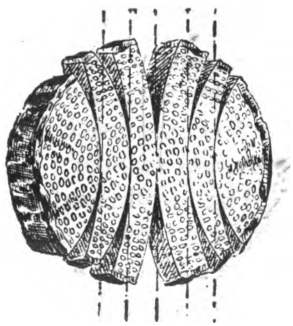


FIG. 4.

which the shrinkage and warping occur. A knowledge of this tendency of wood to shrink and warp in drying is important to possess, and a proper regard for it in joining woodwork will avoid many difficulties.

Pattern-making is of infinite variety, and the pattern-maker is never done learning. New forms and devices are continually appearing; these necessitate constant study and scheming on the part of the pattern-maker to meet the new conditions. An extended range of thought, skill, and experience is necessary for efficient pattern-making. A model of an object is not necessarily a pattern, because it may be made in such a manner that it will be impracticable to mould it.

To become an expert pattern-maker necessitates talents superior to those required for any of the branches of the machine business except designing. The pattern-maker should possess the qualifications of a moulder and also a draftsman, and must be able to read any mechanical drawing readily and conceive the form and intention of the object illustrated by the draftsman, and comprehend its details in the minutest degree. He must be able to determine how and in what manner the object is to be moulded before he can intelligently begin the construction of the pattern, and avoid the errors likely to occur by his inability to do so. Expert pattern-makers are classed with the best general mechanics.

It is a mistaken opinion of some persons that any mechanic working in the trades where the chief material used is wood can work at pattern-making. The pattern-maker is trained to the greatest refinement in the art of working wood. There are few employments which require greater specialized knowledge of rather a wide range than that of pattern-making.

Good carpenters and cabinet-makers can become pattern-makers after the necessary training, their degree of success as pattern-makers depending in a great measure on how great an impression the habits acquired in their respective trades have made upon them.

II.

EQUIPMENT OF A MODERN PATTERN-SHOP.

THE most advantageous arrangement that can be given a modern pattern-shop depends upon the floor-plan.

Assuming that the room is rectangular, of ample dimensions, and is sufficiently lighted on the sides, the most convenient disposition is to place the work-benches along one side and the machines along the other. By this arrangement the dust and shavings can be kept under better control and the transmission of the power to the machines facilitated. Where the dimensions of the floor are about equal lengthwise and across, and there is sufficient room for the benches along both sides, it is advisable to place the machines in the middle or at one end of the workshop. A room in which to keep the various articles used about the shop by the workmen and belonging to the works, such as hand-screws, clamps, and other tools, should be partitioned off. It should be the duty of the sweeper to see that these articles, when not in use, are kept in a place provided for them.

Stands or shelves should be erected at each lathe, and the various attachments, such as chucks, centers, etc., kept upon them when not in use. Similar fixtures should also be provided, where necessary, for the other machines.

The line shaft should run from 250 to 300 revolutions per minute. All wood-working machines require high speeds. With a moderately high speed to begin with, the necessary speed of the machines can be transmitted from the line shaft to better advantage than when a lowerer speed of the shaft prevails.

Wood-turning lathes are indispensable in a pattern-shop, and there should be several of them, their number depending on the number of workmen employed. In a shop having a force of forty pattern-makers at least four lathes are necessary. One of these should be a face-lathe for large diameters, ten feet or thereabouts. Another should be a combined face and tailstock lathe, having an overhanging face-plate capable of swinging pieces of about six feet in diameter, and a capacity of two feet in diameter between the centers. The others should be ordinary wood-turning lathes of smaller capacity, one of which should be suitable for the smallest work. Wooden cones are preferable for wood-turning lathes, and they should be carefully balanced. The speed for wood-turning may vary from 1200 to 2500 feet per minute, according to the nature of the work.

In a shop of the foregoing capacity two circular-saw machines are necessary, both of which should be provided with an iron table and an arrangement by which the vertical height of the saw may be adjusted. One of these should be capable of receiving a saw 28 inches in diameter, and the other a saw 14 inches in diameter. The smaller machines should combine both cross-cut and rip saws, and be so arranged that they can be made to "wabble" for rabbeting.

The usefulness of the machines depends largely on the condition in which they are kept. An excellent system is to have the teeth of circular saws shaped as in Fig. 5, and do all the filing on their front or cutting sides, the backs of the teeth being spiral curves. By this method, when the teeth are all filed equally on their fronts, the saw will be reduced uniformly in diameter, the amount of reduction depending on the spirality of the backs of the teeth and the extent of the filing.

To gum such a saw, a rotary or milling tool should be used. There are various neat little machines of this kind on the market, using mills of various sizes which can be clamped on the saw and the mill revolved by means of a crank, while it is fed to the tooth automatically. The mills make a rounded throat, which should extend slightly under the face of the teeth, so that in filing it will be unnecessary to extend the filing to the throat. This method requires but little filing to keep the saw sharp. If the saw is of sufficient size to admit of the employment of a swage for the setting of the teeth, this method should be adopted, as with it better results can be obtained from the saw than by bending the points of adjacent teeth in opposite directions. An excellent swaging-tool is on the market with which the swaging is done by a cam operated with a lever. The style of tooth here commended is shown at Fig. 5.

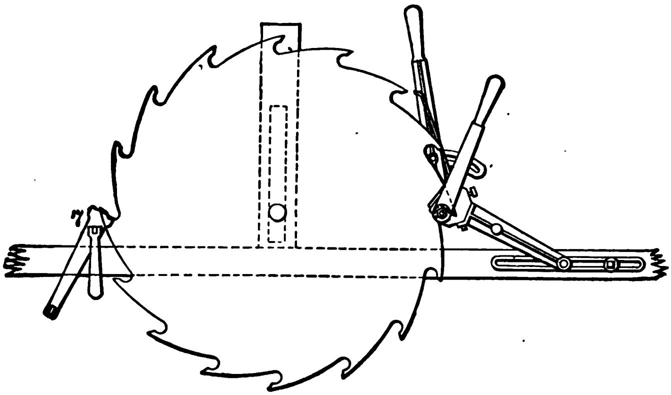


FIG. 5.

The bearings for the arbor of circular saws should be of ample length and babbitted. They require careful attention, and should be taken apart and cleaned periodically, as it is practically impossible to prevent dust working into them.

Circular saws give good results when running at speeds of from 8000 to 10,000 feet per minute.

Circular saws are usually belted so that the revolutions of the arbor cannot be varied. In course of time saws become worn until their diameters are reduced considerably from their original dimensions; consequently there may be several saws of different diameters used on the same arbor, and of course their speeds will vary in proportion to their diameters. These conditions are met and the best results obtained from the machine by driving the arbor to the limit of speed for the largest diameter of saw to be used; that is, at about 10,000 feet per minute for the periphery of the teeth.

A handy device for use when dressing saws is shown in Fig. 5. It consists of a T frame with the horizontal bar secured to a bench. The upright has a slot for the vertical adjustment of the saw. To the right is a swage, whose pivot can be adjusted on the horizontal bar; to the left is a small vise, 7, to receive one tooth of a saw. This vise is adjustable on the horizontal bar, to which it can be clamped by a thumb-screw. By gluing a piece of paper around the end of the file and keeping it bearing on the shelf while filing, all the teeth can be filed alike without difficulty.

The next most important tool for a pattern-shop is the band-saw machine. In a shop of the before-mentioned capacity there should be at least two of these, one to carry saws up to 1½ inches wide, and the other to carry saws up to one inch. One great disadvantage in the use of these machines is the want of stiffness in the frames. There are but few made which are not deficient in this respect.

Band-saws give good results when run at a speed of 3500 to 4000 feet per minute. These machines are usually provided with breaks for the stoppage of the saw, and should always be so arranged that a pressure on a pulley beyond a certain fixed limit cannot be produced by them. If they are not so provided and the saw is stopped very suddenly, it is likely to break in consequence of the strain thus created. A great drawback to the use of these machines is the cost of the saws, which consequently break. That a band-saw will give way in the course of time is inevitable. Every time that a saw passes over the wheels while running, it bends and straightens again. This fatigues the material, and with continued running it is distressed beyond ultimate endurance, just as any similar piece of metal would be broken by being bent back and forth a sufficient number of times.

The breakage of saws may be reduced by careful attention to their condition and that of the machine. In joining them they should be scarfed and lapped two teeth and brazed with silver solder. Immediately the tongs are removed from the joint, a few drops of oil should be dropped on the saw by the side of the lap. If not so treated, the saw is likely to become too soft on either side of the joint and will break there earlier than at any other part.

Band-saws should always be kept sharp and have a proper set to the teeth, and the wooden jaws on the guide-bar of the machine should be kept set up close to the saw. The mouth-block in the table also requires frequent attention, as the deflection of the saws, especially the smaller ones, cuts them away.

An excellent little machine for sharpening and setting band-saws is to be found on the market. It can be secured to a post and occupies little room.

Being driven by power, a saw can be put in, the machine set going and allowed to run without further attention until the saw is finished.

Another important machine in the pattern-shop is a hand-planer. There should be two of these machines, one with 16-inch knives, to be kept for rough work, the other with 24-inch knives, to be reserved exclusively for the cleaner and finer class of work, because, if allowed to be used indiscriminately, the latter will seldom be in the condition essential for the kind of work required of it and for which the machine is specially adapted. The back table of a hand-planer should be provided with a locking arrangement, in order that its position cannot be changed after having been adjusted to the knives.

The speed recommended for hand-planers is 4000 feet per minute, but they will work satisfactorily between that speed and 3500.

A surface or cylinder planer is also a useful machine in a pattern-shop. An improved machine of this kind does not require a great amount of attention; it suffices to have the knives kept in proper condition and the bearings inspected occasionally, to see that the oil is properly performing its functions.

The speed is the same as for the hand-planer. When it is difficult to obtain 4000 feet per minute, a speed between that and 3500 feet will give satisfaction.

A Daniels planer is very useful in a pattern-shop. It is simple, effective and durable, requiring but little instruction regarding its care and use. With this planer the lumber can be planed out of wind, which cannot be done with a cylinder planer, although the work is not so rapidly done as with the latter.

The cutters of a Daniels planer should run at a high rate of speed, say from 10,000 to 11,000 feet per minute. The style of cutters recommended for a Daniels planer are shaped like the letter J, the cutting edge being on the side.

A jig-saw is required in a pattern-shop for inside sawing. The band-saw, which has supplanted it for outside sawing, is not adapted for positions bounded entirely by the material.

An advisable speed for this machine is from 500 to 1000 strokes per minute, according to the character of the machine.

A vertical boring-machine is also useful in a pattern-shop. One having a capacity for boring holes up to 2 inches in diameter is preferable, and should be arranged with two speeds, one to produce 850 or 900 revolutions of spindle, for bits more than $1\frac{1}{4}$ inches in diameter, the other 1200 or 1300 revolutions, for smaller bits.

A core-box machine is another very useful machine in a pattern-shop. A machine of this kind is on the market, on which core-boxes of any length and from $\frac{3}{4}$ to 20 inches in diameter can be worked. Staves and similar pieces can also be worked accurately and rapidly on their hollow sides by this machine.

Among the minor power machines that a pattern-shop should have are a grinder for planer-knives, a wet emery-grinder for bench-tools, and two grindstones, one of the latter being corrugated for the convenience of grinding inside bevel gouges.

Trimmers are indispensable in a modern pattern-shop. It is advisable to have at least two of the largest size for the general use of the shop, and several of smaller size, one being located convenient to each two benches.

There are several other necessary adjuncts to the complete equipment of a pattern-shop, but these are so well known that description of them is here unnecessary.

The bearings of wood-working machinery require very careful attention, in consequence of the high speed at which it revolves and their liability to the deteriorating effects of dust. Bearings should always be provided with tallow-boxes, which should be kept filled with tallow or, better, with Albany grease. A small hole should be made through the grease near each end of the bearing, into which a little oil should be dropped before starting the machine; then, should the oil work off with continuous running, the grease will continue to keep the bearing lubricated.

The foregoing is noted as to machines necessary for the equipment of an up-to-date pattern-shop, one that should be able to perform with precision, expedition, and economy, as far as facilities are concerned, the work required of it.

Of course it is possible to get along, in a manner, with less machinery, but such a shop would be at a disadvantage when competing with a better-equipped concern.

In many shops a great variety of woodwork is done other than that of pattern-making. In such establishments additional machinery is necessary, the kind and quantity of which will be governed by the nature and extent of the work.

The style of work-bench usually furnished pattern-makers is the ordinary carpenter's bench, 16 feet long. Pattern-makers seldom have need of a bench more than 12 feet long, and Fig. 6 represents a convenient style.

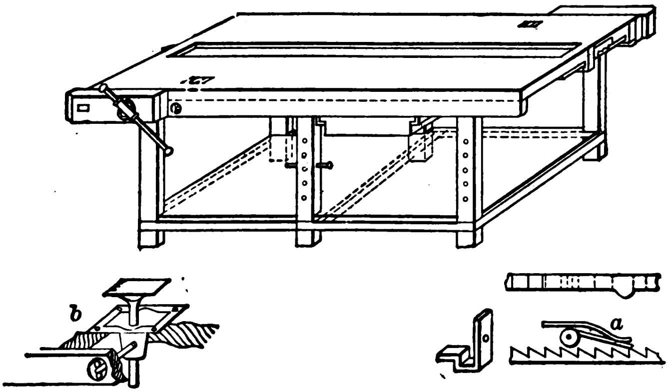


FIG. 6.

The dimensions of a double bench of this kind, well adapted for pattern work, are: 12 feet long, 4 feet wide, and 3 feet high. For a single bench the width should be 3 feet, and the other dimensions the same as for a double bench. Each bench should have a shelf about 1 foot from the floor, extending over the entire space between the legs of the bench. It should also have a drawer for each workman. The framing and the top should be of hard wood about 3 inches thick, except for about 18 inches in the middle of the width of the top; this can be of 1-inch pine placed flush with the bottom of the side pieces, forming a recess in the middle of the bench, as illustrated. This recess is convenient for the retention of small tools and articles to be used about the bench. The jaw of the vise is placed horizontally, and to it is attached a ratchet bar sliding in bearings under the end of the bench. A pawl is fitted into the bench over the bar by means of which the jaw can be adjusted to suit the work to be clamped. This device is shown in detail, marked *a*. The vise-screw is of iron, which works more easily than if made of wood. The above arrangement of the vise is more convenient than the ordinary vertical position, as this necessitates stooping on the part of the workman in order to attend to the adjustment; and rather than do this he will often use the vise in an awkward position, at the risk of resulting damage. Of late years iron bench-vises are becoming much used and are meeting with justly increasing favor.

When sufficient space is available, single benches are preferable. With double benches the space necessary per workman in the length of the bench row is about 5½ feet; with single benches it is about 6½ feet.

III.

THE MANAGEMENT OF A MODERN PATTERN-SHOP.

THE qualifications necessary for a foreman to possess in order to successfully manage the affairs of a large pattern-shop are that he should be a draftsman, a good arithmetician, should have a thorough knowledge of the art of moulding, and should be a good judge of human nature as well as of the different materials used in his department. He should be able to decide the manner in which any pattern is to be moulded, and to direct the construction of the pattern accordingly. He should also have a thorough knowledge of the construction and care of wood-working machinery, and not the least of the necessary qualifications are energy, good character, and good habits.

By some persons the pattern-shop is considered a drawback to the machine business in consequence of the expense because patterns do not show in a completed structure as other materials do, and are considered unproductive. Yet the pattern-shop is more essential than the drawing department, to which it is closely allied. It is possible to dispense with the latter in the machine business, though not with the former where castings are required. But unfavorable criticism of the pattern-shop is frequently the result either of the critic's inexperience in mechanical pursuits, or the assumption of knowledge that he does not possess. The person who invents a method of making castings without the aid of patterns has both fame and fortune awaiting him.

The expense attendant on the use of patterns is often unnecessarily increased, owing to the abuse which they receive in the foundry. Some moulders are veritable pattern-smashers, and will do more damage to a pattern in making a half-dozen castings than others will in making a hundred.

Pattern work, like all other kinds of model work, is expensive, and can be made more or less so according to the work required of the pattern. In this respect patterns may be divided into three classes, and the cost of producing them should be varied accordingly.

a. Patterns of a temporary character, those not likely to be used more than once. These should be made with as little expenditure of labor and material as possible to enable them to perform their functions. These patterns should not be preserved, as they unnecessarily encumber the pattern-loft.

b. A class of patterns likely to be used occasionally, sometimes at long intervals. These should be preserved, and more pains be taken in their construction than with the former, as they have to withstand the usage in the foundry as well as the distortion likely to occur to them during their storage in the pattern-loft.

c. A class of patterns regarded as standard and which are frequently used. These cannot be made too well, and when properly constructed are necessarily expensive in first cost.

When a drawing is received in the pattern-shop the first duty of the foreman in connection therewith is to acquaint himself with it and decide how the pattern is to be made, and in what manner moulded. If detail drawings of a machine or other device to be constructed are received, a general drawing should accompany them, or else the foreman should be made acquainted with the general arrangement of the parts. When this is done he will often be able to detect errors which might not otherwise be discovered until after the castings have been made and the machining of them is in progress.

There are several allowances necessary to be determined previous to beginning the construction of a pattern. The one most troublesome to the pattern-maker is that for finishing. The amount that will answer for one machinist will not suit another. It is advisable to leave as little as possible for finishing, and to have sufficient to allow for the proper finishing of the castings. This allowance will depend a great deal on the result of the casting and its likeness to the pattern. This is likely to vary according to the manner of moulding the pattern. As a rule, the castings requiring the greatest amounts for finishing are those which have been moulded in loam, and castings made of steel. These are liable to vary from the proper dimensions to a greater extent than those moulded by the other methods. Large castings of steel are never as true to pattern as those of other metals.

For patterns to be moulded in loam and for steel castings an allowance of from one fourth to one half of an inch, according to the part to be finished, is necessary.

For ordinary castings moulded in green or dry sand an allowance of from one eighth to one quarter of an inch is sufficient. For the smaller castings, which have been moulded neatly and are of sound metal, an allowance of from one sixteenth to one eighth of an inch will answer.

The allowance for shrinkage, or the amount the pattern is required to be made larger than the intended casting, is another important preliminary matter to be determined before constructing a pattern. The conventional allowance for iron castings is one eighth of an inch per foot, but this rule needs modification in applying it to castings of various shapes, dimensions, and mixtures of metals. To insure accuracy in castings much depends on the judgment of the pattern-maker in providing for their construction. Hard irons, as gun-iron, will shrink more than the above amount, while soft iron will shrink less. Yellow brass will shrink more than bronze. A plain cylinder will shrink less in diameter than in length.

With large cylindrical or box-shaped castings of iron it is good practice to allow one tenth of an inch per foot for shrinkage in length, and one half of this amount in diameter, or across. The shrinkage in length of such castings is generally very little restricted, while in diameter it is resisted by the cores or internal parts of the mould. Two castings of the same weight and of the same kind of material, one of which is extended and the other more compact, will shrink differently, the latter shrinking less than the former.

Metals, like water, are densest in their liquid state, the point of greatest density being near the temperature at which they solidify. From this point they will expand either with a reduction or an elevation of temperature. Iron, when about to solidify, undergoes a sudden expansion, owing to the effort of the molecules to arrange themselves in definite positions. After solidification takes place it begins to contract, with a further loss of temperature. When the contraction begins, the metal is just leaving its plastic condition, and its cohesive strength is considerably below that of its normal state. If at this period the contraction of the metal is resisted by parts of the mould, a fracture of the metal is likely to occur. With some of the more contractible metals, as with steel, to avoid fractures it becomes necessary, as soon as the metal has set, to relieve the interior parts of the mould and allow the metal freedom in shrinkage. In the case of a plain cylinder, where its shrinkage is resisted by an internal core, the metal will contract within its annular wall until its cohesive strength becomes sufficient to compress the core, at which period it will have undergone part of its contraction. This accounts for the reduced shrinkage of cylinders diametrically.

The usual allowances for the shrinkage of castings of different metals are, per foot:

For	iron	one eighth of an inch.
"	bronze	five thirty seconds of an inch.
"	brass	three sixteenths of an inch.
"	yellow brass	seven thirty seconds of an inch.
"	steel	three sixteenths of an inch.
"	aluminum	seven thirty-seconds of an inch.
"	zinc	seven thirty-seconds of an inch.
"	lead	seven thirty-seconds of an inch
"	tin	three sixteenths of an inch.

It is not always known where the castings for which a pattern is to be constructed are to be made. The opinions of moulders will differ widely as to the best method of moulding some patterns. In such cases the foreman is often perplexed. His desire should always be to have a pattern made to be moulded to the best advantage of the foundryman. Where there is any doubt as to the best way of moulding a pattern, the foreman moulder should be consulted where it is possible. As he is responsible for the proper production of the castings, his desire should be regarded and the pattern made for his convenience.

It is too often the case that strained relations exist between the heads of the pattern-shop and the foundry in consequence of the perversity of one or the other, or through attempts made to shift responsibilities. Each should desire harmony in their business intercourse, because without this the work cannot be carried on to the best advantage of their employers.

The foreman of a pattern or any other shop should be relieved of any clerical work. His proper place is in the shop among the workmen, observing what is going on; to inspect and direct the work in progress; to see that every employee is performing his duty properly, and that the materials and machinery are properly used. When he performs all this, he will have little time to devote to office work. With pattern lumber at from seven to ten cents per foot, and where large quantities are being used, it is an important part of a foreman's duty to see that it is economically employed. The repairs to machines, belting, etc., and the sharpening of cutters is quite an item in the running expenses, and the desire should be to reduce this to a minimum.

A foreman should have full control of the employees in his shop as long as he is held responsible for its management. Without this it is probable that by some he will not be respected as he should be. He should be gentlemanly in his intercourse without being too familiar with his subordinates, and should insist on being respected by them. In some instances the responsibility of employing and discharging employees, as well as other duties which should belong to the foreman, are assumed by others above him. Where such a condition prevails, the inevitable tendency is to impair the efficiency of the shop, and it behooves the foreman to use his judgment very discreetly if he desires to reduce to a minimum the annoyances inseparable from such a system.

One thing that reflects credit on the management of a pattern-shop is to have it look clean and tidy. Of course it is impossible, where so many shavings, etc., are made, to have such a shop look as clean as some other kinds of shops. However, it can be kept reasonably clean without an excessive amount of labor by a proper system, making it the business of a person to clean the shop. What helps to make a pattern-shop look untidy is the accumulation of scraps, etc., that litter the floor under the work-benches, thrown there by the workmen for future-use, but who seldom trouble themselves to look through the lot when it is easier to cut a board. This accumulation is aided by the unsuitableness of the ordinary carpenter's work-bench, which is the kind usually supplied to pattern-makers. With the style of bench previously illustrated and described, having under it a shelf about one foot from the floor for the reception of articles not wanted for immediate use, the space under the bench can be swept clean and accumulation of rubbish prevented.

It is too frequently the case that work-benches are unnecessarily abused. Some workmen will use the bench-stop while sawing and thereby risk cutting into the top and vise rather than take the trouble of making a bench-hook. The undue disfigurement of a work-bench is infallible evidence that it has been occupied by a careless and slovenly workman.

The machines in the pattern-shop most likely to cause accidents, as well as to be misused, are the circular saw and the hand-planer. When workmen are careless or ignorant of the use of machines they should be instructed how to use them properly. No saw should ever be forced beyond its limit for doing good work. Even a good saw in the best of condition can be made to work unsatisfactorily by forcing the work too hard upon it. In using a circular saw a person should never place his hand behind it while standing in front, nor even let the hand pass in front of the saw while so standing. A stick should be kept handy, and when the end of the work is near the saw, finish by pushing it through with the stick. Should the saw incline to run out when not forcing it, withdraw the work and investigate the cause, which will likely be one of the following: a dull saw or one with insufficient set. Should the work spring and bind on the saw, withdraw it at once and begin sawing at the other end, or else have some one insert a wedge after the end has passed the saw. Many deaths have been caused by the board being sawn, binding on the back of the saw, which causes the board to be raised until the top of the saw comes in contact with it and throws it forward with great force.

The band-saw is not considered a dangerous tool, but it is liable to great abuse by the use of saws that are too dull or insufficiently set, or by attempting to saw curves smaller than those in which the saw will freely turn.

Nearly every accident occurring on the hand-planer is caused by attempting to plane short pieces which, before they are made to bridge the mouth of the planer, are caught by the knives and drawn in. Often a hand goes in with the piece of work, and the person is maimed for life. A good rule to be observed in using this machine is never to attempt to plane a piece of work on it less than 10 inches long nor less than $\frac{5}{8}$ of an inch thick.

IV.

PATTERN WORK FOR MOULDING IN LOAM.

THE present chapters have not been written with the view of teaching the art of pattern-making, but rather presuppose a knowledge of it; proficiency must be acquired by practical work, patient application, and the stimulus of ingenuity at the drawing-board, bench, and lathe. Aided even by the exercise of these qualifications, only they who possess natural aptitude and who labor long for success can hope to achieve their object and become expert in their profession.

The examples given have been selected from many cases of actual practice, have all borne satisfactory results, and are therefore considered reliable. They are given for the purpose of awakening thought and with the desire to encourage independent suggestion and inventive power; for this will be the surest pathway to a knowledge of the best methods of constructing patterns that will satisfy the varied requirements of the moulder.

In a shop employing a large number of workmen and doing a great variety of work there will always be found those who excel in a particular kind of work. Some will be more expert in one class and others in another. In the giving out of work it is well to consider the efficiency of the workmen in this respect, and, as far as possible, to make a judicious distribution.

When giving out a job the foreman should express to the workman his opinion as to how the pattern should be made and moulded, but he should also listen to and consider any suggestion made by the workman regarding it. Should the workman desire to make the pattern in a different way from that suggested by the foreman, and if a result equal in efficiency and economy can be thereby accomplished, he should be allowed to proceed in his own way, as he will then probably feel a greater interest in producing a good result.

Many good workmen consider it humiliating not to be allowed to use their own judgment as to the manner in which a piece of work should be done, and it is good policy not altogether to disregard their opinions unless they are manifestly at fault, but rather through an interchange of opinion arrive at a mutual understanding.

Men should be dealt with as men, and boys as boys, and not the reverse, which is sometimes attempted.

Loam moulding is resorted to when the article wanted is of too large dimensions or is too complicated in form to be moulded by any other method, or when the casting is not likely to be often duplicated. It is considered the most intricate, varied, and expensive method of producing castings, whether of iron, brass, or steel. On the other hand, the pattern work for loam moulding, while often very intricate, is of the most inexpensive kind.

Patterns for loam moulding are both of the simplest and the most complicated kind. The simplest are for bodies of revolution, or those objects which can be formed by revolving a radial section of the body about an axis. One of the simplest examples is the pattern work for a large plain kettle. These comprise a number of sweeps or strikes, in some places called strickles. A sweep consists of a plain piece of board whose profile is that exposed by a plane cutting the body parallel with and passing through its axis.

The first sweep used in constructing a mould for a kettle is that marked A, Fig. 7. It is secured to

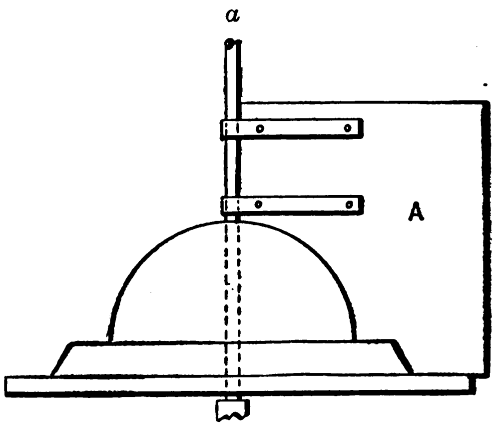


FIG. 7.

the spindle, *a*, which is free to revolve about a vertical axis. The mould is built up of brickwork, with a thickness of loam intervening between it and the edge of the sweep, and, when the latter is revolved, it strikes or dresses the loam off to the form of the sweep. This part of the mould, when completed, is called the core, and forms the inside of the kettle.

The next sweep is used to form the thickness of the kettle. This is marked B, Fig. 8, and it super-

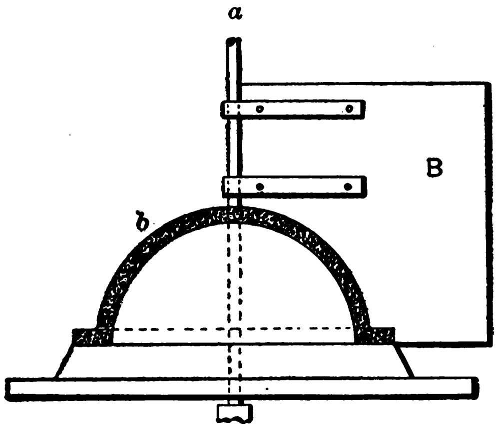


FIG. 8.

sedes sweep A on the spindle. Prepared moulding sand, *b*, is placed around the core and is swept to the outside form of the kettle by revolving the sweep. This concludes the function of the pattern work necessary for the job. The moulding is continued by building up brickwork, strengthened with plates, with a thickness of loam intervening between it and the moulding-sand thickness.

When it is of great importance to insure a dense and solid bottom the kettle is moulded in the reverse position, bottom down. This is a somewhat more expensive method than the former. When moulded the latter way the sweeps are made the reverse of those described, and are used in the reverse order.

V.

PATTERN WORK FOR A CYLINDER.

LARGE cylinders, with nozzles such as are used in beam engines, are objects well adapted to be moulded in loam. They require somewhat more pattern work than the former example. Fig. 9 represents a section of mould for a cylinder of this kind.

When preparing the pattern work for such a cylinder the first piece required by the moulder is the sweep, Fig. 10. This is used to form the seat or foundation of the mould. After the seat has been swept up and the sweep removed the seat is lined off. The segment, Fig. 11, is the next in order, and is made of board the thickness of the bottom flange of the cylinder and having an inside radius equal to that of the outside of the flange. It is set as illustrated, and moulding sand is rammed inside of it to form the pattern of the lower flange of the cylinder.

The next piece in order used is the outside or cope sweep, Fig. 12. This being secured to the spindle, everything is prepared for the building of the outside of the mould. The patterns of the nozzles, Fig. 13, being prepared, they are set by lines in their proper positions during the building of the outside of the mould. The outside flange seen on the

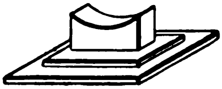


FIG. 13

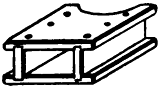


FIG. 15.

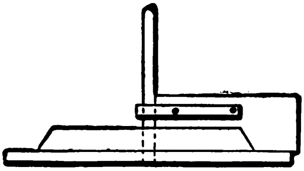


FIG. 10.

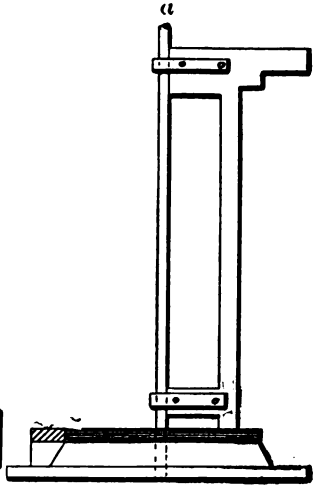


FIG. 11. FIG. 12.

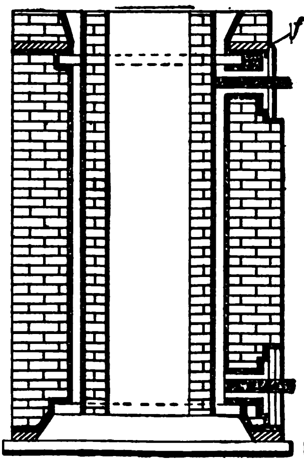


FIG. 9.

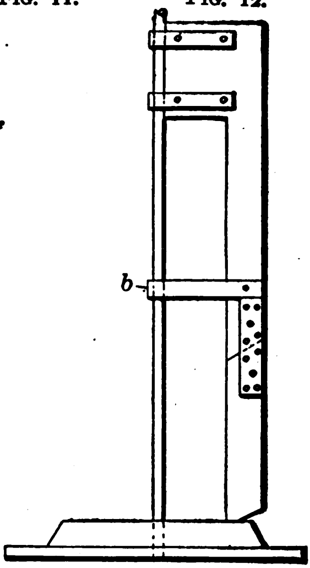


FIG. 14.

nozzle pattern is to form a seat for a covering-plate. These plates have holes through them, through which the nozzle-cores pass. The outside wall, or cope, of the mould being finished as far as the top of the upper flange and the sweep, Fig. 12, removed, the cope is then removed from the seat, leaving the latter intact.

The main core sweep, Fig. 14, is next attached to the spindle, as illustrated. When the cylinder is a very long one, it is advisable to make this sweep in two pieces, batten them together and apply an additional spindle-arm, *b*, above the batten. When the core has been built up above the joint in the sweep, the lower part of the sweep, as well as the extra spindle-arm, can be removed and the building of the remainder of the core proceeded with. The core is extended about one foot above the top flange for the purpose of providing for a head to be cast on the top of the cylinder to receive the impurities of the metal and insure the solidity of the upper part of the casting. When the main core is completed it is left standing on the seat and dried in that position.

The cope plate, *f*, is next prepared, and is usually a cast-iron plate, one side of which is provided with prickers. This side is covered with loam and swept off with a straight sweep. When dry it is inverted and the mould extended on the upper side and made to form the outer wall of the head. The mould, when completed, presents an annular opening at the top, through which the metal is poured and drops to the bottom. Fig. 15 is the core-box for the nozzle-cores, and Fig. 9 represents a section of the mould when assembled.

A column of cast iron 3.84 inches in height and of one square inch in area weighs one pound and exerts that pressure per square inch on its base when in a liquid state.

Assuming the foregoing cylinder to be 16 feet or 192 inches in height from the bottom to the head, the pressure will consequently be fifty pounds per square inch on the bottom of the mould. This great pressure has a straining effect on the mould—a tendency to separate its walls. If the walls of the mould are parallel with each other, that is, have a uniform distance between them from top to bottom, the casting would probably show a greater thickness of metal at the bottom. It is advisable, therefore, to set the sweeps to counteract this straining of the mould by the metal.

For a cylinder 10 or 12 feet in height the core should be made one eighth of an inch larger in diameter at the bottom than at the top, and the outer wall one eighth of an inch smaller in diameter at the bottom than at the top. The mould would then measure one eighth of an inch less between its walls at the bottom than at the top, but the thickness of the casting would most likely be uniform, owing to the straining effect of the metal on the mould while being filled. For a cylinder of 15 or 18 feet in height this difference between the walls of the mould at the top and the bottom can be increased to three sixteenths of an inch.

The result of pressure on the liquid metal in a mould is to increase its density and strength when cold. In some instances moulds are arranged to receive a pressure in addition to that produced by the metal alone, as in the case of the Whitworth process of casting steel. Even should the mould not be strained to the extent allowed for, the casting will be strongest at the bottom, owing to the benefit resulting from the greater pressure there.

VI.

PATTERN WORK FOR AN ELBOW.

In constructing loam moulds it is not always necessary to have a spindle. Other bodies than bodies of revolution can be swept up in loam when the necessary guides are provided for the sweeps. Figs. 16 to 31 represent a large valve-chamber combined with a nozzle, or elbow, or bend. Fig. 16 is a frame made of $\frac{7}{8}$- or $1\frac{1}{8}$-inch material. The interior of the frame corresponds with a horizontal section of the casting. The size of the opening at each end is extended in the frame for the same purpose that core-prints are made to form a seat, or support, as well as a guide for setting the core. The outside of the frame is worked off, to be parallel with the inside, for the purpose of forming a guide for the sweeps. Fig. 17 is the pattern for the flange at the valve-chamber end; Fig. 18 that of the end of the bend; Fig. 19 is the pattern to form the bell shape where the diameters change; these are shown attached to plate 16. A pattern for this part is not absolutely necessary, as it can be formed by sweeps; but a pattern facilitates the moulding; Fig. 20 is the pattern for the branch, or nozzle; Fig. 21 is the sweep to form the outside of the mould at the bottom or drag part of the bend, and Fig. 22 that for the inside; Fig. 23 is the sweep to form the outside of the mould in the drag for the chamber, and Fig. 24 that for the inside; Fig. 25 is the sweep for the core-print of the drag at the valve-chamber end, and Fig. 26 is the sweep for the core on the cope side of the bend; Fig. 27 is that for the outside of the bend; Fig. 28 is the

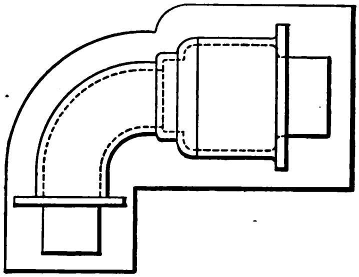


FIG. 16.

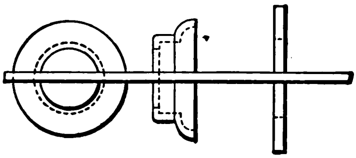


FIG. 16.

FIG. 18. FIG. 19. FIG. 17.

sweep for the inside, or core, of the chamber on the cope side, and Fig. 29 that for the outside; Fig. 30 is the sweep for the core-print on the cope side. All of the necessary pattern work being prepared as described for the construction of the mould, its building can be proceeded with.

A foundation-plate is first prepared, upon which the mould is to be built. The frame, Fig. 16, with the lower or drag parts of the pattern screwed thereto is set up on the plate, and brickwork of the usual kind for loam moulding is built up to the frame, Fig. 16. While building up the mould the

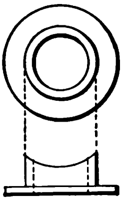


FIG. 20.

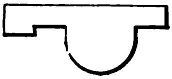


FIG. 21.

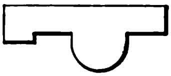


FIG. 22.

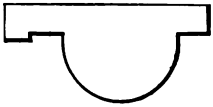


FIG. 23.

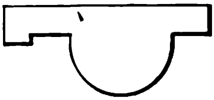


FIG. 24.

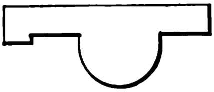


FIG. 25.

FIG. 26.

FIG. 27.

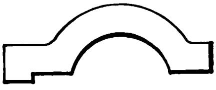


FIG. 28.

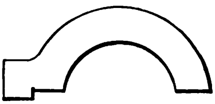


FIG. 29.

FIG. 30.

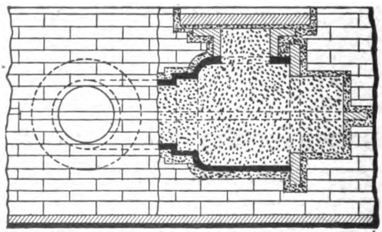


FIG. 31.

proper sweeps are used. The sweep Fig. 21 is used to form the outside of the mould by moving it around the bend with the semicircular part projecting downward and the straight parts resting on the frame, while the projection on the end of the sweep is kept bearing against the edge of the frame. The sweep Fig. 23 is used in a similar manner to form the outside of the chamber. The sweep Fig. 22 is used like Fig. 21, to form the core-seat at the end of the bend.

The mould for the outside of the casting being finished on the drag side, it is then dried, after which a thickness of green sand equal to that of the metal is worked around the inside of the mould, as shown by dotted lines, the sweeps Figs. 22 and 24 being used for the purpose in a manner similar to that of Figs. 21 and 23. The thickness being completed, the core is made on the inside up to the top side of the frame. The patterns for the upper or cope part of the flanges, Figs. 17 and 18, also that for Fig. 19, are placed in their proper positions, and the building of the core is continued on the cope part of the mould, the sweeps Figs. 26 and 28 being used to reduce the core to its proper shape. After the core is completed, green sand equal in thickness to that of the metal is worked around the outside of the core, and the sweeps Figs. 27 and 29 used to reduce it to the form of the outside of the casting. The core-print on the cope side at the chamber end is formed by the sweep Fig. 30. The branch or nozzle, Fig. 20, is now set in its proper position on the pattern as formed. The core of the nozzle, which is made within the latter, is made to connect with the main core. The mould is then completed by the building up the cope half. The nozzle is made to be withdrawn from without, and a loam plate is made to cover the flange of the nozzle. When the mould is disjointed, the impression made by the frame, Fig. 16, is filled in.

Nozzles are made to set at various angles on the chamber. In some cases more than one is cast on it. It will sometimes be advisable to make the nozzle pattern solid, with core-print attached, and have a separate core for it.

Fig. 31 illustrates the mould in part section when its building up is completed.

VII.

PATTERN WORK FOR STEAM-CYLINDER OF MARINE ENGINE.

THE pattern of a large steam-cylinder, with steam- and exhaust-passages, when moulded in loam, demands a greater proportionate amount of detail than is required by those described already. The pattern work can be made more or less elaborate, according to the manner in which the moulder desires to proceed in order to construct the mould.

The following pattern work and method of procedure have been applied with successful results in producing satisfactory castings of large cylinders.

Fig. 32 shows a plain view, Fig. 33 an elevation, and Fig. 34 a section of a casting designed for a low-pressure cylinder with receiver for a compound engine.

When a loam mould is to be made for such a cylinder the pattern-maker is required to prepare the necessary pattern work before the moulder can proceed with its construction.

The cylinder is moulded inverted; that is, the open end, or that which is upward when it is in the engine, is moulded downwards.

The first piece required is the seat, or foundation sweep, Fig. 35. This sweep forms a level surface,

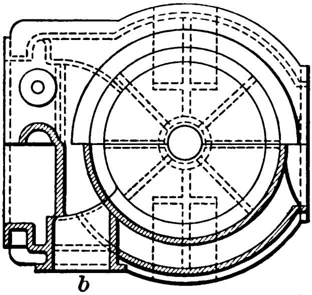


FIG. 32.

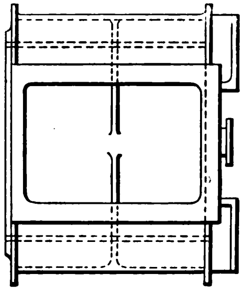


FIG. 33.

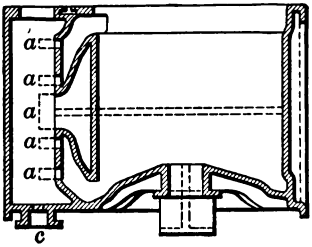


FIG. 34.

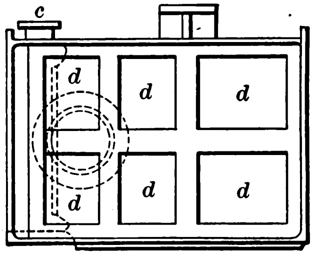
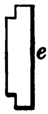


FIG. 36.



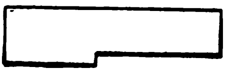


FIG 35.

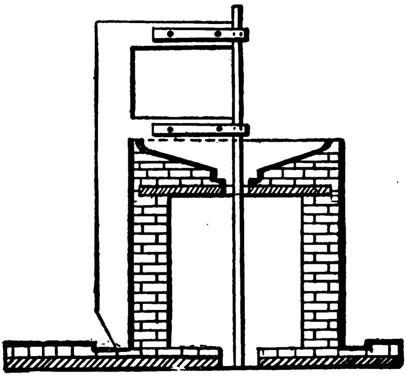


FIG. 37.

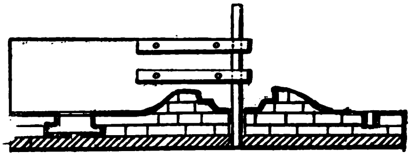


FIG. 38.

FIG. 39.

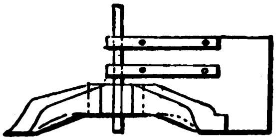


FIG. 40

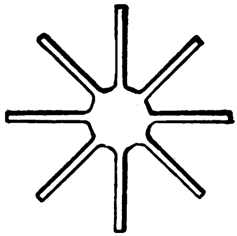


FIG. 41

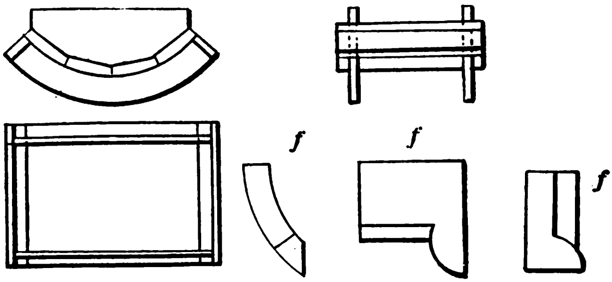


FIG. 42.

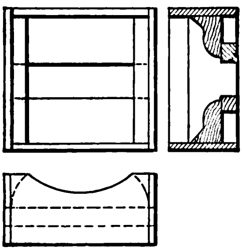


FIG. 43.

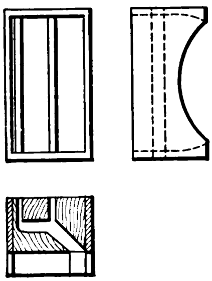


FIG. 44.

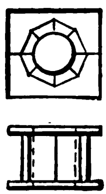


FIG. 45.

upon which the pattern work is placed; and it also forms the flange facing, against which the cylinder-head is bolted. Fig. 36 represents a framework of wood. Its exterior is the form of the exterior of the casting. It also contains the valve-chest, which is the same in form as that represented in the sectional view, Fig. 34, except that where the openings are shown in the valve-face core-prints are placed, as shown by the dotted lines *a*, *a*, etc., projecting from the valve-face. These core-prints are for the purpose of locating and supporting the cores for the induction and eduction passages. The cylindrical parts can be formed with revolving sweeps, secured to a spindle, which method is preferred by some moulders; but a framework of wood is preferable in cases of this character, as with it there is less difficulty in retaining the parts in their proper positions. The flanges projecting inward in the valve-chest are screwed or put on with draw-pins, in order that they may be released and withdrawn outwardly. The framework is made in sections and screwed together to facilitate its being taken apart and withdrawn from the mould. The patterns for the exhaust-nozzle *b* and nozzle *c* are made blank and cored out with special cores inserted from the outside of the mould.

The foundation, or seat, being prepared and lined off, the framework is placed upon it and properly located. Everything is then prepared for the building of the cope, or outer wall of the mould, to be proceeded with. The framework has open places, as *d*, *d*, etc. When the mould is being built up past these places, a strike, *e*, is used from the inside to shape these parts of the mould. When the exterior of the mould is completed to the top of the upper flange it is struck off by a plain sweep fixed at right angles to the spindle. A line is drawn across the top of the mould through the center of the cylinder and valve-chest, and another line at right angles to the former and through the axis is also scribed on the top of the mould. These lines are for the purpose of locating the position of the covering-plate of the mould. When the exterior of the mould, which has been made in sections, is sufficiently dry to handle, it is removed from the seat, leaving the latter intact.

The framework is then removed from the seat, after which the main-core sweep, Fig. 37, is secured to the spindle and the main core built up on the seat, where it is dried and dressed and remains undisturbed. A core-seat is formed in the upper part of the main core, into which a core is set to core out the hole in the head of the cylinder for the plug which contains the stuffing-box for the piston-rod. Previous to setting the core the main core is filled with sand, as a precaution against accident, the metal being liable to make its way into the interior of the core during the filling of the mould.

The cover of the mould, or cope-plate as it is sometimes called, is made to form the head of the cylinder. It is a plate provided with prickers, and is specially cast for the purpose. When preparing the mould upon it it is inverted, as shown in Fig. 39, and a spindle is erected at its center. The sweep Fig. 38 is secured to the spindle, and a surface conforming to the shape of the top of the ribs and flange of the cylinder-head is swept up. The parts of the casting which project beyond this surface, such as the flange of the stuffing-box for the valve-stem and the brackets by which the cylinder is secured to the housing, are represented by patterns which are accurately located and bedded into the loam during the sweeping up of this surface by the sweep Fig. 38. The patterns for the nozzle for the stuffing-box plug and the radiating ribs being prepared, they are properly placed upon the surface last swept up, and another sweep, Fig. 40, is employed to sweep off the top of the cores. The ribs for the cylinder-head, with the sweep Fig. 40, are shown apart from the plate at Fig. 41. When the mould on the plate is finished it is marked with lines at right angles to each other to correspond with those scribed on the top of the exterior of the mould. The covering-plate is set on the mould by these lines.

The core to form the receiver, or that part of the casting between its inner and outer walls, in some cases is the usual brickwork of loam moulds; in other cases a series of cores made in a box and joined together to form the required part are used. This latter method is preferable, as it possesses the merit of being much more easily cleaned out of the casting, although greater care is required in preparing the vents.

At Fig. 42 are shown three views of a core-box for receiver cores. The cylinder herein described will require eight of these cores, two in height and two around each side. The box is made a segment of ninety degrees, but the cores complete will not extend so far. They are made the required size and shape to fit the mould by placing stopping-off pieces in the ends of the box. *f* shows such a piece for stopping off the cores. Where the exhaust emerges it requires two of these pieces, one right- and one left-hand. Two more of the proper form, right and left, are required to stop off the cores which go to the open side opposite the valve-chest. Fig. 43 represents the box in which the core for the exhaust-passage is made. Three views are shown—plan, elevation, and section. The box is made to be taken apart.

Fig. 44 shows the box in which the cores for the steam-passages are made. These passages are of the double-ported variety. Three views of these are shown—plan, elevation, and section. Fig. 45 represents the core-box for coring out the cylinder-head nozzle, into which is fitted the plug containing the stuffing-box for the piston-rod.

VIII.

PATTERN WORK FOR A PEDESTAL.

Occasionally a large casting of some kind is called for, a duplicate of which is never likely to be required. To make in the usual way a pattern for such a casting would consume considerable time, which might cause delay as well as involve unnecessary expense. In such cases, therefore, recourse is had to temporary expedients. Fig. 46 shows such a casting in the form of a tapered pedestal, whose length and comparatively small diameter are such as to make it inadvisable to sweep it up vertically, after the manner of making a cylinder mould, or to incur the expense of constructing a pattern of the usual kind. It being decided to cast the pedestal in a horizontal position, a barrel, upon which the core is made, is the first piece required. The pattern of the core-barrel will be formed by strikes, or sweeps, guided by proper templet, the skill of the moulder being called in to form the pattern after the pattern-maker has provided the necessary appliances. Fig. 47 illustrates a section of the mould and pattern for the core-barrel. An iron flask is first constructed which, when very long, as in the present case, is made in two pieces. The usual brickwork of loam moulds is built inside the flask, and the guide *a* is set at one end of the drag, the guide *f* at the opposite end, and guide *c* midway between the two. When thus arranged, their circles are such that when a straight-edge is moved around the inside, the required uniform taper will be produced. The middle guide is not absolutely essential, but with it the strike need be only one half the length of the mould, thus being more conveniently handled. *h* is the sweep for forming the lower or drag half of the mould, and being half the length of the latter, it is used alternately at each end. The recess in the mould formed by the offset on the sweep *h* represents the thickness of the casting. When the mould is sufficiently dry this recess is filled in with green sand, and a straight-edge moved around the guides reduces it to the proper thickness. This last operation completes the lower half of the mould and pattern. The core is next made on the inside of the mould up to the joint. The guide *b* having been set in *a*, and *g* in *f*, these determine the diameter of the upper half of the core. The half-collar *d* is set midway between the other two for the convenience of a guide for the sweep, which is a straight-edge, of half the length of the mould. When the core is formed the collar *d* is removed and its impression in the core filled in. The core being sufficiently dry, the half-collar *d* is set midway of its length, and green sand is placed around the core; the sweep *i* is then used to reduce the sand to the thickness of the intended metal. This completes the core and pattern for the upper

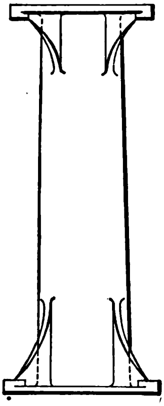


FIG. 46.

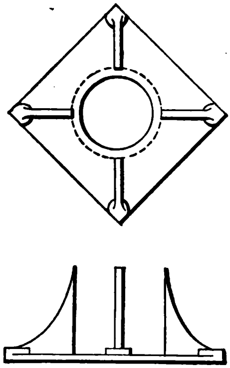


FIG. 49.

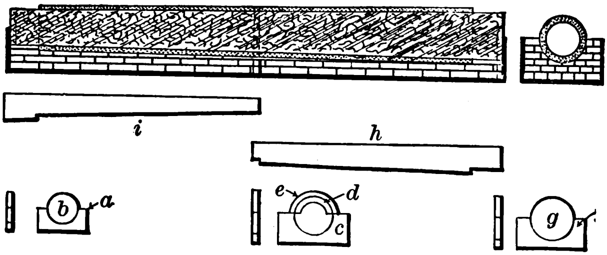


FIG. 47.

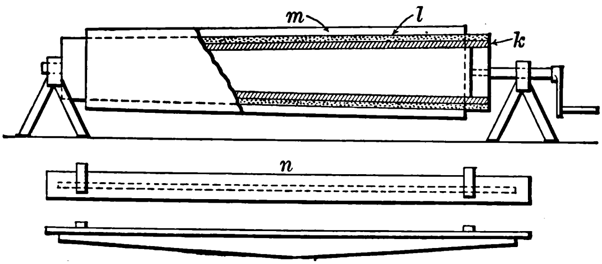


FIG. 48.

or cope half of the mould. The mould is then completed in the usual manner. The illustration shows the various guides and sweeps for the core in the relative positions which they occupy in the mould, but separated from it.

When the mould is taken apart and the core lifted out, the thickness of green sand is removed, and the mould and core are then finished in the usual manner. Numerous small cores, the same length as the thickness of metal, are fixed around the mould for the purpose of casting holes in the core-barrel. The core-barrel *k*, being cast, is mounted between bearings, as illustrated at Fig. 48. The core is made in the usual manner by winding the barrel with rope made of hay, then coating this with loam, *l*, and reducing the loam to the required size and shape by revolving the core while in contact with one side of the sweep *n*, which is so set as to obtain the proper diameter of the core.

When the core is sufficiently dry, which is accomplished by building a fire under it while it remains in the bearings, a second coat, *m*, of specially prepared loam is laid on and brought to the required thickness, which is equal to that of the metal, by revolving the core, while the reverse edge of the sweep *n* is fixed so as to reduce the loam to the required diameter. This being accomplished, the second coat forms the pattern for the body of the pedestal. When this outer coat is dry and dressed it is ready to receive the top and bottom flanges,

Fig. 49, ribs, bosses, and whatever else is necessary to complete the pattern.

These parts are made of wood, and are fitted to the pattern formed for the body of the pedestal, the flanges parting through their center and the bosses arranged so that they can be drawn in through the vacancy left by withdrawing the flanges.

The pedestal pattern is supported in a horizontal position when it is being made, the supports being under the gudgeons which project from the ends of the core-barrel. The mould is constructed of brickwork in the usual manner of constructing loam moulds. When the mould has been completed and taken apart the coating of loam representing the thickness of metal is removed from the core and the latter dressed. After the mould has received like treatment it is reassembled.

IX.

PATTERN WORK FOR SCREW PROPELLERS WHEN SWEPT UP IN LOAM.

ONE of the most interesting objects swept up in loam, and which to be successful requires considerable skill and experience on the part of the pattern-maker and moulder, is a large screw propeller cast entire.

Figs. 50 to 56, inclusive, show the preparations necessary to be made by the pattern-maker when the mould of a large screw propeller is intended to be swept up in loam.

Fig. 50 represents the guide, or directrix, upon which the blade-face, sweep, or generatrix travels to produce the helicoidal surface. The guide is usually set six inches beyond the periphery of the blade, to allow for the joint of the mould.

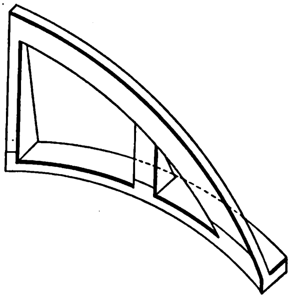
At one time guides were made of plate-iron cut to the proper angle and secured to a base of wood after being bent to the required curvature. The term "guide-iron" was derived from this method of making them. A guide made entirely of wood is, however, preferable.

Fig. 51 illustrates how the curvature of the guide may be obtained. An arc of a circle of the radius of the position of guide from the axis is described for the base. The degrees of the arc should be somewhat greater than the angle occupied by the blade when it is viewed parallel with the axis, in order to allow for a joint at both the top and bottom edges of the blades. The arc is divided into any number of equal parts, as *a*, *b*, and *c*. The length of the inclined rail is obtained by laying down its angle with one end intersecting one extremity of the base line, and the other end intersecting a perpendicular from the other extremity of the base. The length of the rail is divided into the same number of equal parts as the base and ordinates of like letters made equal in length. A curve drawn through the extremities of the ordinates will be the elliptic arc, to which the rail is to be worked. In constructing the guide, the rail is left sufficiently wide to allow for finishing the top edge, which is the last work done on it. To lay off the guide a line is described parallel with the base and about four inches from the bottom, which is to allow for a joint in the mould. The length of this line, or arc, will be that intersecting radial lines which are tangent to the edges of the blade when it is viewed parallel with the axis. The arc is divided into equal parts, and it is advisable to have one of the intersections in the center, to be used as a center line. Perpendiculars are erected from the intersections, and the length of the ordinates for the angle of the guide laid off on them. A thin strip, or batten, is then tacked on the inside of the rail, intersecting the extremities of these ordinates. A line drawn along the top of the batten on the rail will be the guide line. The rail is to be worked off to this line, a try-square, with the stock held vertically, being used to gauge the shape of the edge.

For a screw of uniform pitch the guide line developed on a plane is a straight line. For a screw of expanding or increasing pitch the line developed is a curve, the ordinates for which should always be given on the drawing.

Fig. 52 is a thickness piece representing a section of the blade at the first division from the hub, and Fig. 53 represents a similar section, the first division from the periphery. These should be made of pine board about three fourths of an inch thick, and are curfed with a saw for about three fourths of their thickness. The curfs are made parallel with the axis of the screw, and the distance between them should be such as to permit the thickness pieces being bent to the line marked for them on the pier by the notches in the blade-face sweep. The thickness pieces are secured to the piers with nails.

Fig. 54 is the sweep for the foundation, or seat; Fig. 55, that for the hub; and Fig. 56, the sweep for the generatrix, or face of the blades. Sweep Fig. 56 is made of plain board about 1¼ inches thick. The generatrix, or working edge of the sweep, is made of various shapes, according to the ideas of the designer. In the present case it is a right line perpendicular to the axis of the screw. The distance between the hub and the periphery is divided into as many parts as there are thickness pieces to be



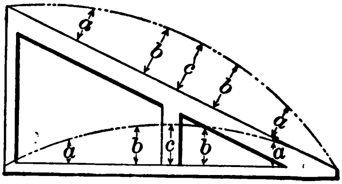


FIG. 51.

FIG. 50.

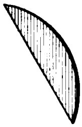


FIG. 52.

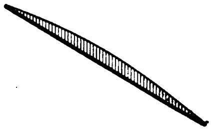


FIG. 53.

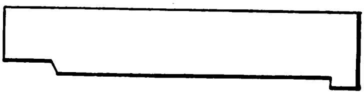


FIG. 54.

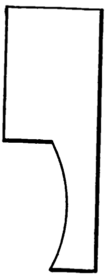


FIG. 55.

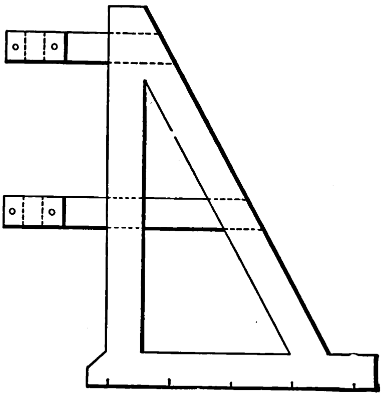


FIG. 56.

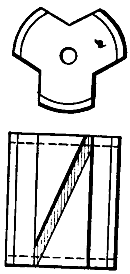


FIG. 57.

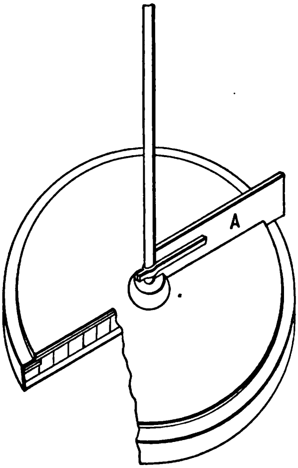


FIG. 58.

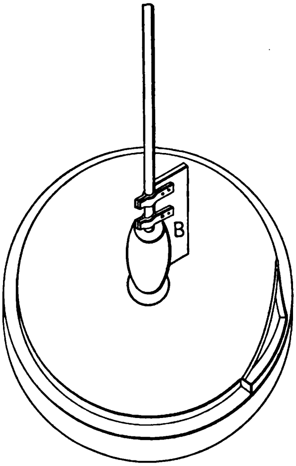


FIG. 59.

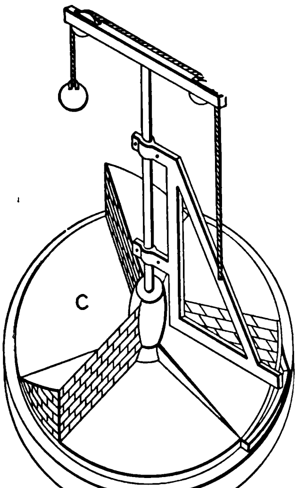


FIG. 60.

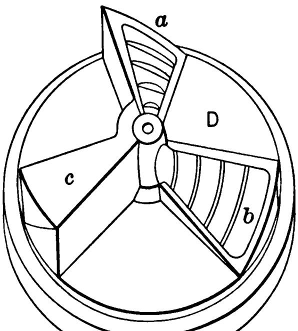


FIG. 61.

used. At each division on the sweep a small notch is cut in the working edge; these notches leave a marked line on the face of the pier, by which the thickness pieces are set.

The sweep Fig. 54 forms an elevation, or seat, on which the hub rests, and also a depression at the outer end, on which the guide sets. After the seat has been dried it is lined off according to the number of blades required. The sweep Fig. 55 forms the pattern for the hub, which is usually built of brickwork and covered with loam, and shaped by revolving the sweep around it. The guide is next set in its proper position, and weighted to prevent its moving. The sweep Fig. 56, for the face of the pier on which the blade pattern is built, is now placed on the spindle and counterpoised, as illustrated at Fig. 60, to permit of its free movement up and down the spindle. The arrangements are now complete for the building of the pier to be commenced.

It is necessary that the sweep Fig. 56 should move by the hub to a small distance below the lower edge of the blade. The sweep is thus left at this part without support, and it will invariably spring and finally cause the face of the pier to become somewhat distorted near the hub. To remedy this it was the practice of the writer to provide guides at the hub as well as at the periphery. These are shown at Fig. 57. If the screw is a small one, a half-hub, with the guide cut in it, may be used and shifted around for the several blades. If the screw is a large one, a framework of wood, having as many cylindrical faces as there are blades, is provided. It is made somewhat less in diameter than the least diameter of the hub. A curfed strip is nailed on each of the cylindrical faces at the required angle according to the radius adopted, and these form the guides for the inner end of the sweep Fig. 56. When this arrangement is used nails are driven into the cylindrical faces, to hold the loam with which it is covered; it is reduced to size and shape by a hub sweep. When sufficiently dry the loam is cut away to expose the guides.

Fig. 58 shows the seat completed; Fig. 59, the hub swept up and the guide set. Fig. 60 illustrates two piers completed and one in course of building. At Fig. 61, *a* illustrates one pier as lined off with the thickness pieces in position. Another pier, *b*, is shown with the pattern of the blade formed by filling in sand between the thickness pieces and dressing it off to the shape of the blade. The other pier, *c*, shows the cope, or upper part of the mould, which covers the blade completed upon it. After the copes are all completed the mould is taken apart and stripped of the patterns of the hub and blades.

When a sweep at one end follows the axis and the other end the guide, the pitch will be uniform radially. It is sometimes desired to have the pitch variable in a radial direction, or a less pitch at the axis than at the periphery. In such a case the sweep is required to travel with a lower axial velocity at the hub than at the periphery. At Fig. 62 a device is shown by which this can be accomplished. The proper guides are provided at the hub and periphery. Two arms, each having a hole in its end, are secured to a spindle, which is free to turn with the arms. A rod is made to slide freely up and down through the holes in the arms. The sweep is pivoted to the lower end of the rod, and its ends made to bear on the two guides. The height of the blade at the hub and at the periphery being determined, with a proper allowance for the guide being beyond the periphery of the blade, the distance on each guide is divided into the same number of equal parts. Consequently the vertical distance of a space on the hub guide will be less than one on the peripheral guide. The sweep is then made to travel through a space on the hub guide and a space on the peripheral guide in the same time. The other arrangements necessary to complete the mould are similar to those previously described.

The foregoing is descriptive of the method of preparing moulds for propellers where the thickness of the blade is all on one side of a radial line. In some cases the thickness is given on both sides of a radial line equally, similar to a V thread; in other cases the thickness is unequally divided by such a line.

When the thickness of the blade is all on one side of a radial line, the generatrix is the line exposed by a plane cutting the screw parallel with and passing through the axis. The plane of the sweep

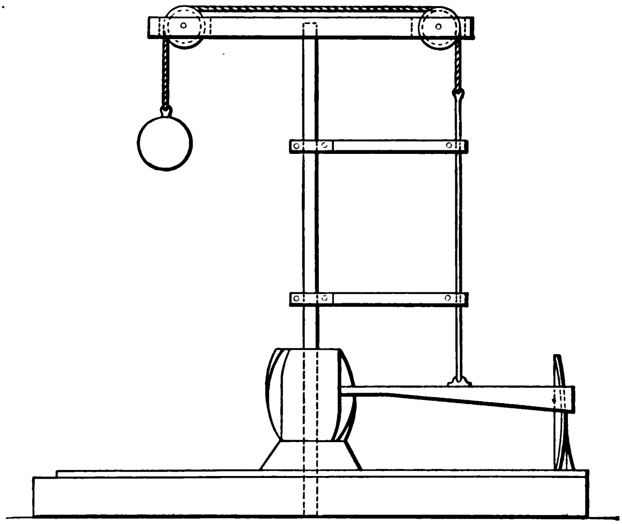


FIG. 62.

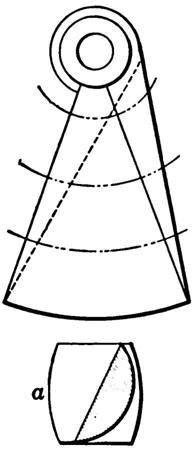


FIG. 63.

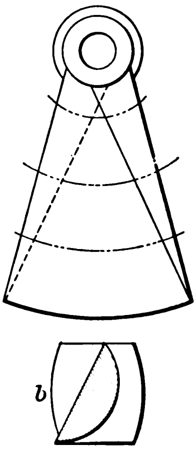


FIG. 64.

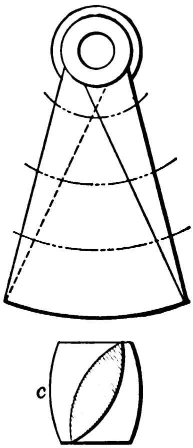


FIG. 65.

must lie in the same plane as that cutting the screw.

It is possible to generate the face of a screw by the line exposed by a plane cutting the screw perpendicularly to the axis, the sweep lying in the same plane; but the vertical plane for the sweep is preferable.

When the thickness of the blade is divided by a radial line, the generatrix is the line exposed by a plane cutting the screw parallel with but passing outside of the axis, the degree of obliquity depending on the way in which the thickness is divided.

When the generating line is not a right line perpendicular to the axis of the screw, but a line of unusual form, occupying some peculiar position with reference to the axis of the screw, it becomes quite a difficult problem to work out the line on paper. The writer has found it convenient to work this out, as well as many other tedious problems. to a scale on white-pine blocks, and then develop the line from the one resulting.

What is meant by the thickness being on one side of a radial line is shown by Fig. 63, where the thicknesses are exaggerated. Fig. 63 is a plan view, and *a* a section, of such a blade. Fig. 64 is a plan view of a blade where the thickness is on both sides of a radial line, the face of the blade being flat or straight; *b* is the section of the blade. Fig. 65 is a plan view of a blade where the thickness is also on both sides of a radial line, but the face and back of the blade are convex alike; *c* is a section of the blade.

When the thickness of the blade is on both sides of a radial line and the face of the blade is flat, as shown at Figs. 63 and 64, either of the devices shown for sweeping up propellers can be employed, provided the pitch is uniform radially; but when the section of the blade is like that of Fig. 65, or when the pitch is not uniform radially, the device shown at Fig. 62 is alone applicable. With this device the sweep is fixed at right angles to the rod when the pitch is uniform radially, and pivoted thereto when the pitch is not uniform. When the latter device is used, and the face of the blade is convex, the guide at the hub is so shaped as to produce the required convexity.

Figs. 66 to 69 show a working drawing of a two-bladed screw propeller. The arcs *a*, *b*, *c*, *d* on the plan view are intended to represent sections of the blade at these points. These arcs are developed into straight lines as shown, and are then projected to furnish the basis of the angles A, B, C, and D. The length of the blade measured axially being determined, it is laid off at one end of these base lines and perpendicular to them, the triangles being completed by a hypotenuse drawn between the extremities of each of the base and perpendicular lines. This hypotenuse is the length of the section of the blade developed. The greatest thickness of the blade at each of these sections being determined, it is laid off in the center of the hypote-

FIG. 69.

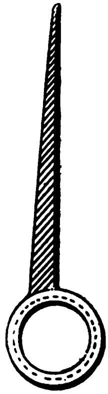
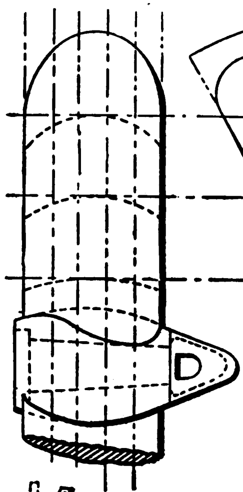
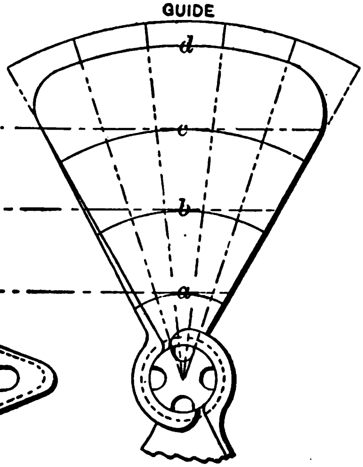


FIG. 68.





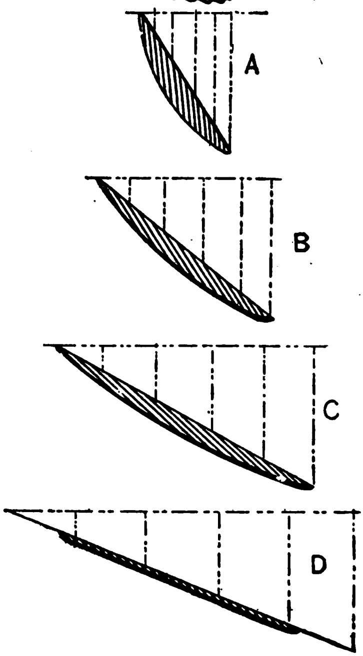


FIG. 66.

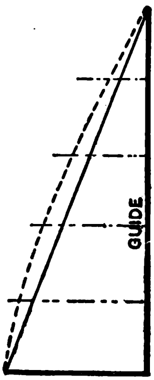


FIG. 67.

nuse, and an arc of a circle described through the extremity of this thickness dimension and tangent to arcs of one-half inch radius at the ends of the hypotenuse incloses the developed area of the section of the blade it represents.

These sections furnish the forms and dimensions of the thickness pieces. These are made of pine board about three fourths of an inch thick. Fig. 66 shows a thickness piece which has been curfed with a saw, in order that it may be bent to the required curvature, the curfs being made parallel with the axis of the screw. Fig. 67 shows the angle of the guide, whose base is also the length of its arc developed.

The full hypotenuse line, which is a straight one, is the developed guide line for a true screw, and the dotted line is the guide for a screw of expanding pitch. Fig. 68 is a side elevation of the screw, and Fig. 69 is a scale of thickness through the thickest part of the blade. The sections represented should always be given on a working drawing.

When the screw is of expanding pitch, the lengths of at least five ordinates for the curvature of the guide line should be given.

X.

PATTERN WORK FOR RIFLE-PROJECTILES.

DRY-SAND moulding is adopted chiefly for large and intricate castings requiring solidity and accuracy of form. It is a somewhat less expensive method of producing castings than by moulding in loam, especially when the castings are to be duplicated. Dry-sand moulds are made of specially prepared sand, and are dried in an oven or a heated room; consequently metallic flasks become necessary.

Patterns designed for moulding in dry sand do not materially differ from those intended for green sand. In some cases, however, they can be formed of fewer pieces, as cores and drawbacks are frequently made in the mould of the same material as the mould itself, and to better advantage than if made in separate boxes.

Projectiles designed to carry explosives must be free from porosity to avoid the liability of the charge they contain becoming ignited by the firing of the gun, with the result of a premature explosion of the shell. When such projectiles are made of cast iron every precaution is taken to secure dense and accurate castings. The location of the core in reference to the exterior of a rifle-shell is very important. Should there be eccentricity of the interior with the exterior, the flight of the projectile is effected and the accuracy of aim is destroyed.

Figs. 70 and 71 show a 13-inch rifle-shell. Fig. 70 is the pattern and Fig. 71 the core-box. The pattern is made solid, preferably of baywood. When large, as in the present case, two- or three-inch lumber is glued up until the desired size is obtained. A bar of 1½-inch round iron, provided with a collar, is fitted through the center of the block and screwed half-way into a nut let into one end of the block, and the collar on the bar is let into the opposite end of the block. The remainder of the thread in the nut is for the double purpose of securing an eye-bolt when the pattern is to be withdrawn from the mould, and also to secure a center when the block is to be placed in the lathe. The end of the bar projecting outside the pattern contains a center, and the pattern is swung between those centers while being turned. The projecting bar, or center pin, is also turned so as to be concentric with the pattern. The pattern which is shown in the flask, with the position of the core dotted, is moulded in the position shown, and the draft or taper is toward the point of the shell. A cylindrical projection is made at the point of the shell to provide a sinking head.

The core-box is made in sections as illustrated, segments of baywood being glued and nailed in the usual manner to form them. The sections are

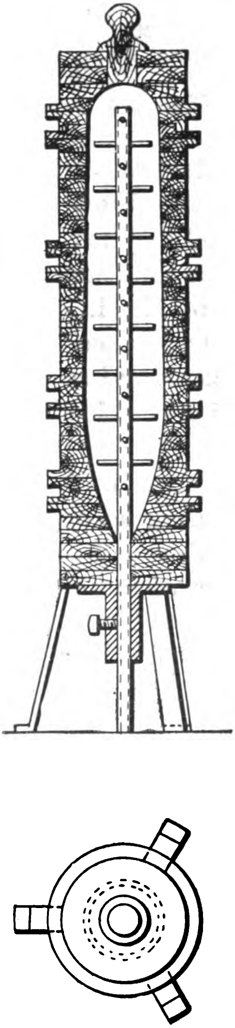


FIG. 71.

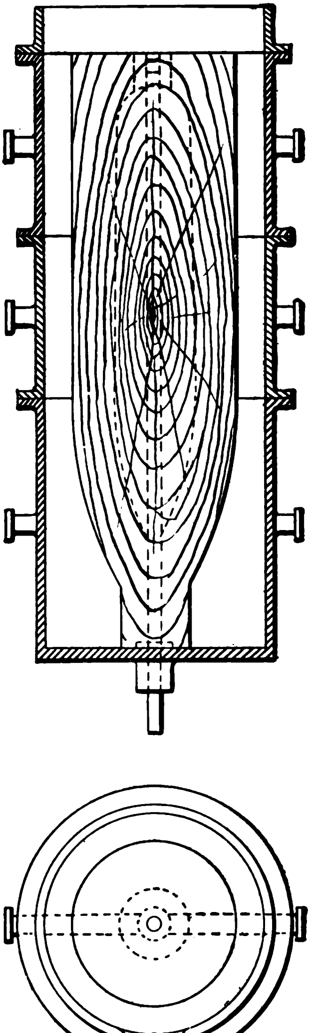


FIG. 70.

made to match by turning a projection on one end of a section and a corresponding recess on the end of the adjoining section. The core being tapered allows the sections to be drawn from the core in an axial direction.

The first or lower section of the core-box is fitted with a sleeve, which is for the purpose of holding the vent-tube concentric with the core. The vent-tube performs two functions, that of carrying off the gases from the core, and supporting the core in position in the mould. That part of the vent-tube covered by the core is perforated with numerous holes, and small pine sticks are placed in these holes to assist in venting the core as well as to help secure it to the tube. The shells are moulded in a vertical position in special brass flasks, made in sections to facilitate ramming up. The first section of the flask has a cross-bar with a boss in the center of the flask; a hole through this boss corresponds with the diameter of the bar projecting from the pattern, also with that of the vent-tube projecting from the core. By this means, when the vent-tube is secured in the hole, the core is brought concentric with the mould. The core is set while the mould remains as when the pattern was drawn. After the core is set the mould is inverted and the shell cast with its point uppermost.

XI.

PATTERN FOR LAUNCH-ENGINE.

FIGS. 72–86 represent the pattern for an 8×8 launch-engine. The cylinder, valve-chest, frame, and bed-plate are combined in one casting.

Fig. 72 shows a plan, Fig. 73 a front elevation, and Fig. 74 a side elevation of the pattern. Fig. 75 shows a section of the cylinder through the steam- and exhaust-passages. The pattern is arranged for moulding with the valve-chest down, or in the drag, and is made to part through the axis of the cylinder.

In making the pattern of the cylinder it is preferable to use well-seasoned lumber of thickness sufficient to allow of its being turned to the required dimensions without the gluing together of several pieces. To do this, lumber some five inches thick is required. In turning the cylinder, scores of about one quarter inch deep are made where the flanges are located; the latter are sawed out and fitted into these scores, being there glued and nailed and finished with the remainder of the cylinder.

The open or top end of the cylinder has a core-print turned there. In length it is about equal to that part of the core which enters the cylinder in order to obtain sufficient support for the core, as

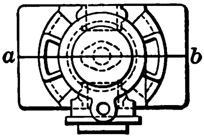


FIG. 72.

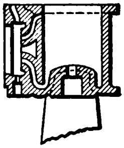


FIG. 75.

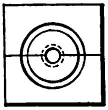


FIG. 76.

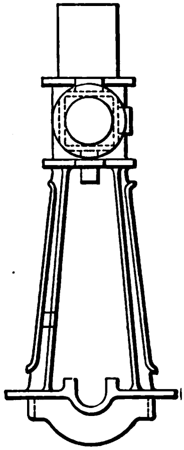
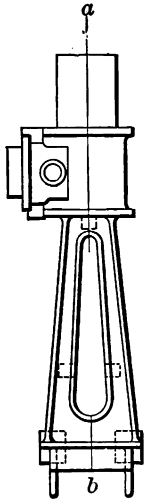


FIG. 73.



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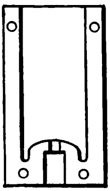


FIG. 77.

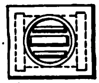


FIG. 78.

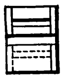


FIG. 80.

FIG. 79.

FIG. 81.

FIG. 82.

FIG. 83.

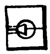


FIG. 84.

FIG. 85.

FIG. 86.

little can be had from the opposite or stuffing-box end, in consequence of the small diameter of the core there.

The lower end of the cylinder has a cavity or recess turned in it, into which the pattern of the stuffing-box is fitted. The stuffing-box with its attached core-print, like the body of the cylinder, is made in halves and attached to the latter by dovetails in such a manner that it can be lifted out with the main core without affecting the cylinder.

The main core is that which is formed below the cylinder and between the framing or housing and bed-plate. As commonly said, the pattern leaves its own core in that part.

The bed-plate is made by framing together four pieces of the required thickness, of width sufficient to allow the plate to be reduced to the required shape. After the plate is worked to shape and lined off, the bearings for the shaft are added, and also the ribs or flanges which project below the plate. It is then sawed through the center of the bearings with a thin saw and the two halves dowelled to make it part in the same plane as that of the cylinder.

The framing consists of conical-shaped frames, placed opposite each other, and which connect the bed-plate with the cylinder. Each is made in two pieces which part in the same plane as that of the cylinder and bed-plate, viz., on the line *ab*. In fitting the framing to connect the cylinder with the bed-plate, a surface board is first prepared and lined off. The dowel or drag halves of the cylinder and bed-plate are secured to this board in their correct relative positions.

The drag halves of the frames are let into the cylinder about one and a half inches and secured there with glue and screws. At the opposite ends the frames are fitted against the bed-plate and glued to it; screws are also driven from the under side of the bed-plate into the ends of the frame. A large fillet is glued and nailed around the frame and to the bed-plate, and this aids materially in making the pattern more rigid at that part.

The drag halves of the cylinder and bed-plate being secured to the framing, the pattern is released from the board and turned over; the cope halves of the cylinder and bed-plate are placed upon their drag halves, the cope framing being secured to them in a similar manner to that adopted with the drag.

The valve-chest is fitted and secured to the drag half of the cylinder, the flange is fitted to the chest with steady-pins, but separates from it in the mould where a parting is made to enable the flange to be withdrawn.

Figs. 76 and 77, respectively, show an end view and an elevation of one half of the core-box for the cylinder.

Figs. 78 and 79 show a plan and a section of the core-box for the valve-chest.

Figs. 80, 81, and 82 show a plan, a section, and an end elevation of the core-box for the steam-passages.

Figs. 83, 84, 85, and 86 show a plan, an end elevation, and a longitudinal and transverse section of the core-box for the exhaust-passage.

In moulding the pattern, which is done in an iron flask, the drag part is laid upon a follow-board, and a box representing one half the main core is put between the frame to form the parting there. The mould is rammed up to the face of the valve-chest flange, a core is placed over the flange to cover it, and the mould is then continued until it surrounds the core. The latter is then removed and the pattern of the flange taken out, after which the core is replaced and the ramming of the drag completed. The flask being turned over, the box representing the main core is removed and a lifting-plate for the core is placed in the bottom of the space it formerly occupied. The main core is built upon the plate up to the parting. The cope half of the pattern is now placed in position and the main core is continued to completion. The cope of the mould is next completed and removed with the cope part of the pattern, leaving the stuffing-box in the main core. The latter is now lifted out and the stuffing-box removed from it. The main core being out of the way, the drag half of the pattern is withdrawn from the mould.

More than one hundred castings have been made from a single pattern of baywood as thus described.

XII.

PATTERNS OF DECK-LUG FOR DRY-SAND MOULDING.

In constructing large patterns to be moulded in dry sand it is frequently advantageous to arrange them for moulding somewhat after the manner of constructing loam moulds; that is, to permit of the mould being made in sections which can be lifted away from the seat or foundation of the mould. The main core can then be made and finished on the seat and be allowed to remain there. The sides of the mould, which are sometimes called cheeks, are assembled around the core. This plan obviates handling the core, which may be large or of such a shape as to make the safe handling of it very difficult.

Figs. 87–94 represent such an object, which is a deck-lug for a gun-mount. Three views of the casting are given—a plan (Fig. 87), a side (Fig. 88), and an end elevation (Fig. 89).

The pattern is moulded with the bearing downward. The ribs, flanges, and other parts projecting from the sides are arranged to be removed with the cheeks. Fig. 88 also answers for the side view of the pattern when completed. The dotted

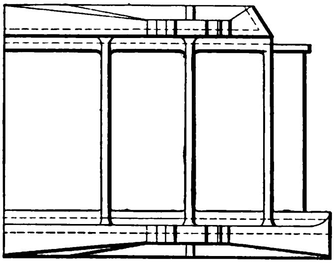


FIG. 87.

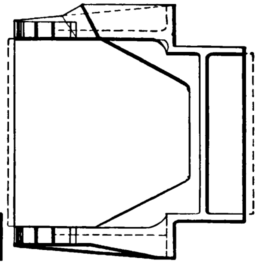


FIG. 89.

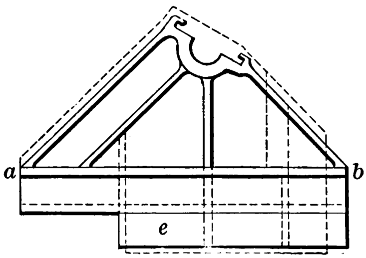


FIG. 88.

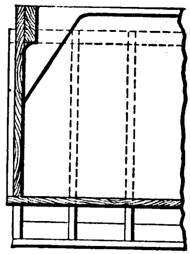


FIG. 92.

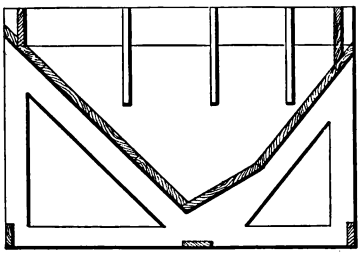


FIG. 90.

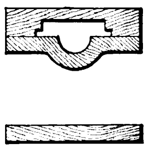


FIG. 93.

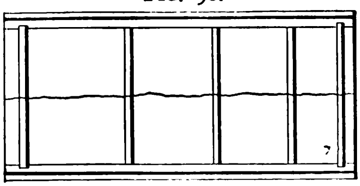


FIG. 91.

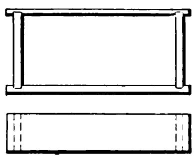


FIG. 94.

lines outside the inclined ends represent the core-prints for the main core. The pattern separates or parts on the line *ab*.

In constructing the pattern a number of frames made of 2-inch lumber are first provided. These frames should be about 1¾ inches less all round than the section of the pattern where the frames are located. The frames are set up and properly arranged according to the position they are to occupy in the pattern; they are then covered with boards a little in excess of 1¾ inches thick; these are secured to the frames with screws and glue, the holes for the screw-heads being counterbored and plugged after the screws are in.

When the box so formed is dressed down to the proper dimensions it forms the body of the pattern upon which the outside ribs, bosses, flanges, and other projecting parts are secured. This is done with draw-pins, screws being also used to insure the parts against shifting until the pattern is set up for moulding. The draw-pins are removed as the mould is being built up.

Shallow core-prints are fitted to the two inclined sides of the pattern for the purpose of locating the core-box when placed upon the seat of the mould. The upper or cope part of the pattern, *e*, is constructed in a manner similar to that described in the foregoing.

Three views are given of the main core-box, Fig. 90 being a longitudinal section. The plan, Fig. 91, not being correct to scale in width, is shown broken through the middle. Fig. 92 represents a half cross-section of the box.

The main core-box is constructed by first preparing a bottom board, which is secured to frames having the angles of the pattern where the core-prints are located. The sides and ends of the core-box are erected upon the bottom and are screwed together so that they can either be taken apart or removed from the bottom without being taken apart.

The bottom board of the main core-box is not essential, absolutely, when the core is made in the place it is to occupy in the mould, as here intended. But by having it the box is better retained in shape, and, if so desired, the core can be made and set in the mould afterwards, as commonly done.

Fig. 93 shows the box for the trunnion-bearing cores, and Fig. 94 the box in which the cores are made for the cope part of the pattern. These are plain boxes and require no further description.

In moulding the pattern there is first prepared a seat or foundation corresponding in shape to the part of the pattern where the core-prints are located, and the pattern is placed upon this seat. The sides or cheeks of the mould are then built up and arranged to be lifted away from the mould without affecting the seat. The ribs, flanges, etc., on the sides of the pattern are lifted away with the cheeks, the pins and screws which secured them to the sides of the pattern having been withdrawn when the cheeks were being built up. The cope, or cover, of the mould is also completed before the mould is taken apart.

After the cheeks are removed the main core-box is lifted from its bottom and placed upon the seat of the mould, according to the position marked by the core-prints; the core is then completed and allowed to remain on the seat. When the mould is being assembled the rectangular cores are supported on chaplets placed upon the main core.

XIII.

PATTERN WORK FOR WATER-COLLAR.

FIGS. 95–104 represent a water-collar and the pattern work for it.

Water-collars are used in connection with the gun-turrets of war-ships, and consist of two principal parts; one of these is fixed and the other revolves with the turret. Water, under pressure, passes into the collar through a branch in the outer member, thence to a central passage in the inner member, and through it to the motors in the turret. The exhaust-water returns by another pipe, through an annular passage in the inner member, and thence through an outlet branch in the outer member. These castings are quite intricate; their patterns are interesting examples of pattern work, and considerable skill is required in their construction.

Fig. 95 shows a side elevation and Fig. 96 a section of the device when assembled. The glands used for making the collar water-tight being ordinary glands, they are omitted.

Fig. 97 shows a plan and Fig. 98 a side elevation of the pattern for the inner member; it is made in halves, the pattern parting on the line *ab*. The core-prints *c*, *d* form bearings to support the central core, and the prints *e*, *f*, bearings for supporting the annular core. Fig. 99 shows one half the box in which the central core is made. The annular core is made in halves. Fig. 100 shows a plan and section of the box in which the half-cores are made. These cores cut through the outside of the casting at *g*, *h*, where prints are located on the pattern to assist in supporting them in the mould, as well as to aid the venting. The holes so made are plugged in finishing the casting.

In making the box for the annular core a bottom board of sufficient size, and which should be battened to prevent warping, is first prepared. Upon this board is fitted the body *y*, representing the outside of the metal inclosing the central passage. Two pieces, one right- and one left-hand, shown by dotted lines, are made for the upper end of this part where the bend is located. By interchanging these pieces both halves of the core can be made from the same box. To form the outside of the core, two pieces, *x*, one right- and one left-hand, are worked out on the inside to the outside form of the core over the bend; an opening, *e*, is cut through one side of the pieces to form the outlet opening in the side of the casting, where the core-print, *e*, is located. By interchanging these pieces to correspond with the bend the opening is made to match when the halves of the core are set in the mould. Fitted to the opposite end of the box is a piece, *n*, worked out to form that part of the core which lays in the impression made by the print *f*. The strike, *i*, is for the purpose of shaping the part of the core between the two end pieces.

After this part of the core is struck off, the piece *k*,

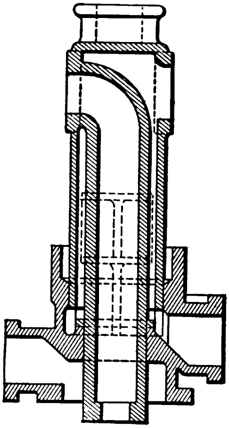


FIG. 96.

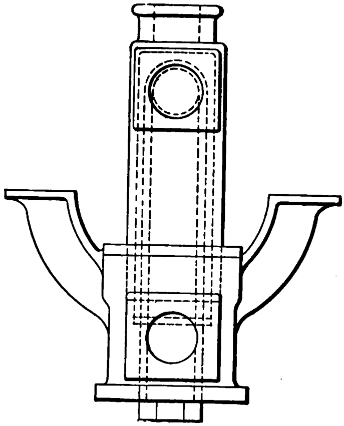


FIG. 95.

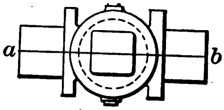
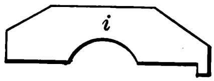


FIG. 97.



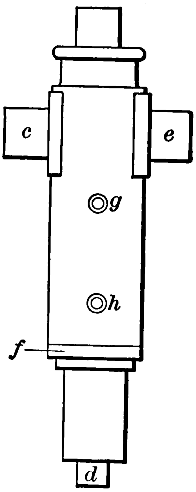
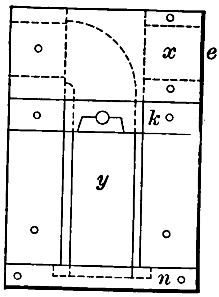


FIG. 98.



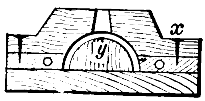


FIG. 100.

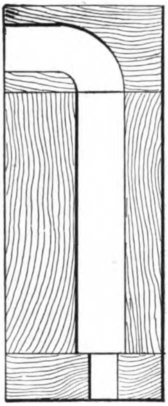
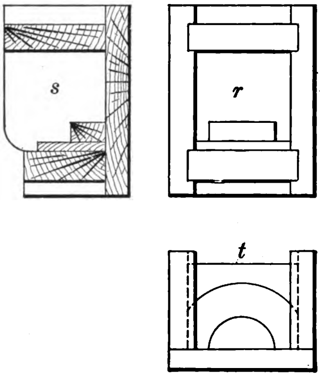


FIG. 99.



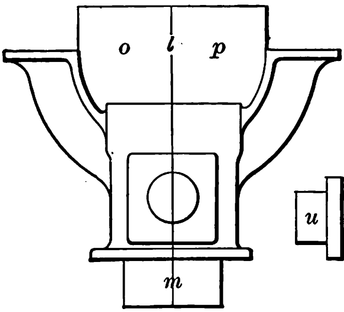


FIG. 101.

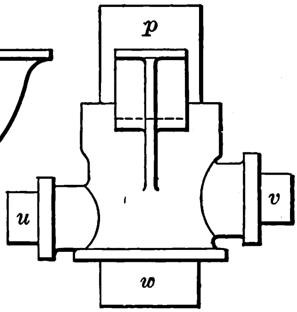


FIG. 102.

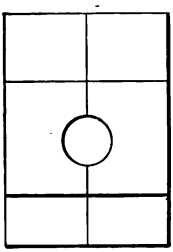


FIG. 103.

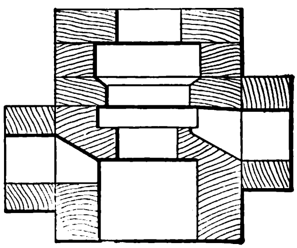


FIG. 104.

which has dowel-pins to fit holes provided to locate its position on the board, is placed over the core and the small branches *g* and *h* are added to the main part by extending the core through the hole in piece *k*. The square hole or socket in the upper end of the casting is formed by an ordinary square core.

Fig. 101 shows a side elevation and Fig. 102 an end elevation of the pattern for the outer member, which has two supporting brackets attached. The pattern is in halves, and is made to part on the line *lm*. The spandrel between the brackets is formed by two similar cores, one of which is secured in the drag, and the other in the cope part of the mould. The core-prints *o*, *p* form the bearings for supporting these cores, which contain a bearing for the upper end of the interior core. When the mould is closed the cores meet at the joint of the mould. One elevation, *r*, and two sections, *s* and *t*, of the box in which these cores are made are also shown.

Fig. 103 shows an end elevation of the box in which the interior core is made.

Fig. 104 shows one half the box viewed from the interior. The box is built up of several pieces, as the illustration indicates; this facilitates working out the different diameters contained in the box. After being worked out the several pieces are assembled and secured together.

The core is supported in the mould by the bearings made by the core-prints *u*, *v*, and *w*, and by the bearing in the cores between the brackets.

XIV.

PATTERN WORK FOR HIGH-PRESSURE CYLINDER FOR MARINE ENGINE.

FIGS. 105–117 represent a more intricate casting made in a dry-sand mould. It shows the high-pressure cylinder of a compound engine having a valve-chest and a receiver combined with the cylinder. Fig. 105 is a half plan and half cross-section and Fig. 106 is a vertical section through the axes of the cylinder and valve-chest.

Prior to commencing the construction of such a pattern its position and the method of moulding must be decided. Having chosen a horizontal position, the pattern will be made to part or separate through the axes of the cylinder and valve-chest on the line *ab*.

Four frames of 2-inch lumber are prepared. These frames extend beyond the cylinder proper, or casting, and the core-print for the receiver core is formed on this extension. Each frame is made in two pieces, the joint running through the axes of the cylinder and valve-chest. The contour of each frame is less by about 1½ inches than the exterior of the finished pattern. The finished exterior is illustrated in Fig. 107.

A frame is placed at each end of the pattern, the other two being set intermediate and equidistant between the end ones, as shown at Fig. 108. The frames are covered on their outer edges with staves running parallel with the axis of the cylinder, as shown in Fig. 109. The staves are made of 2-inch lumber, and are secured to the frames with screws and glue. After dressing the ends of the staves fair with the frames, the pattern is lined off, and finished to this line by removing the surplus material with planes. The screws having been countersunk, to avoid coming in contact with the tools, the screw-holes are filled by plugs.

The lower head of the cylinder is cast in; that is, it is made a part of the casting. To form this head in the mould a piece is built up of segments, and turned to the required shape and dimensions. The frame at the proper end of the cylinder is cut away sufficiently to allow the insertion of the turned piece, which is secured to the pattern, as shown in Fig. 108, where is also shown a section of the pattern through the axes of the cylinder and valve-chest. The piece forming the nozzle with core-print attached is fitted to the head, and is made to lift out of it when the mould is being separated. This relieves that portion of the mould forming the head, which parts as does the pattern and allows of removal from the flask after the mould is opened. When this part of the mould, or drawback as it is sometimes called, is removed, the pattern is free for withdrawal from the mould.

The part of the pattern that forms the valve-chest is made in halves, with a core-print at each end. It is built up of staves, in a manner similar to that of the body of the cylinder, and, being of moderate size, is turned to the proper shape and dimensions in a lathe. The valve-chest is secured to the other part of the pattern with screws and glue. The projections on the valve-chest that form the outer walls of the steam-passages are next fitted, after which the part containing the induction-passage and nozzle is fitted and secured to the valve-chest. This piece is made to part like the other portion of the pattern, and is worked out of solid material, the core-print and flange being turned and added to it.

The top and bottom flanges, which extend all around the ends of the cylinder and valve-chest, are next added, after which the brackets by which the casting is secured to the engine framing are added; also the bosses for the relief-valves and facings for the hand-holes, etc., are fitted. The core-print for the upper or open end of the cylinder is built up of segments and turned to dimensions. It is secured to the end of the cylinder with screws and glue.

The pattern is now ready to be cleaned off and to receive its coat of shellac. The completed pattern is shown in Fig. 107.

A plan and a sectional view of the core-box for the receiver core are shown respectively in Fig. 110 and Fig. 111. It is a half-box, the one box answering for both halves by having right and left pieces, *c*, *d*, which are secured in the box according to the half of core to be made.

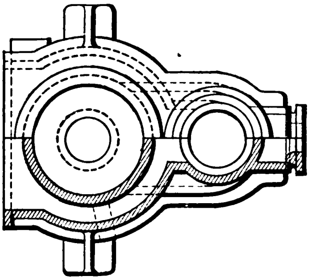


FIG. 105.

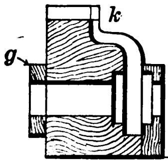


FIG. 114.

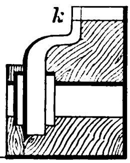


FIG. 115.

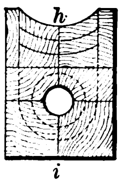


FIG. 116.

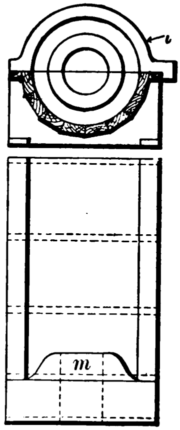


FIG. 117.

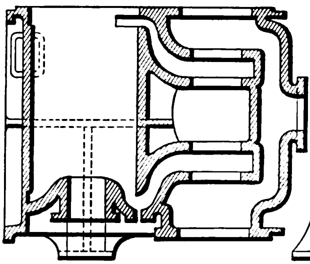


FIG. 106.

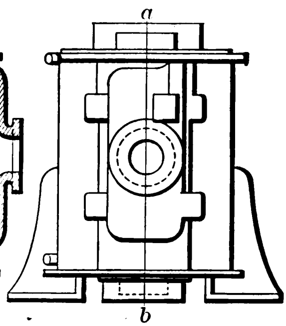


FIG. 107.

The box is constructed by first preparing a bottom board, then fitting together the sides and mounting

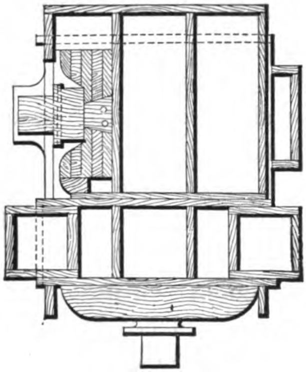


FIG. 108.

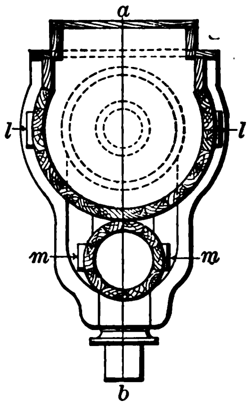


FIG. 109.

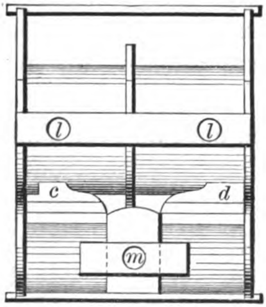


FIG. 110.

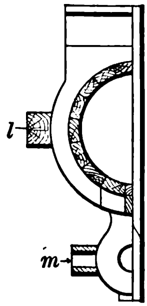


FIG. 111.

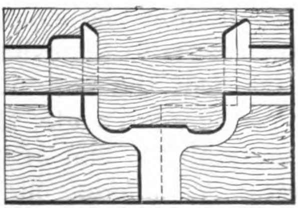


FIG. 112.

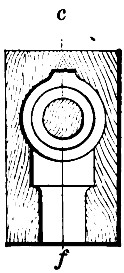


FIG. 113.

them on the board. The half-cylinder which forms the inner wall of the receiver is constructed by preparing heads and securing staves to them, which, when worked off, will produce the required cylindrical dimensions. The upper edges of the sides are worked to the outer shape of the core, a straightedge being used to sweep off the core to the form of the sides of the box.

Each half-core is supported in the mould at the open end of the receiver, at two places on the cylinder, *l*, *l*, and at one on the valve-chest, *m*, where the cylindrical openings cut through the outer wall of the casting. The corresponding letters on the core-box show where the core is extended for this purpose. The openings are plugged up in course of finishing the casting.

Fig. 112 illustrates the core-box for the induction-passage to the valve-chest. The view shows the inside of one half the box when separated. Fig. 113 shows a section through both halves of the box. This core is made in halves, the parting being on the line *ef*, and it is supported in the mould at the three ends where core-prints have left impressions. A cylindrical opening is made through the core for the purpose of providing support for the cores for the steam-passages to the cylinder.

Fig. 114 represents one half the box in which the cores for the steam-passages are made; the box is made to part or separate on the line *hi*. Two of these cores are necessary, differing in length where they pass through the induction-core. One core is made with the piece *g* attached to the box, and one, Fig. 115, for the upper passage without it. The box is made open on the upper side, *k*, to facilitate ramming the core up. These cores are supported in the mould on one side by the induction-passage core, which they pass through, and on the other side by the exhaust end of the receiver core. It is necessary to support them also by chaplets.

Fig. 117 illustrates the core-box for the interior of the cylinder. Two views are shown, a plan and an end view. For that part of the core containing its large diameter a half-box for the lower half of the core is sufficient, the upper half of the core being formed by a strike, *l*, which is shown in the position in which it is used. It is advisable to make both halves for the other end of the box, which contains the smaller diameter.

The part projecting inwardly, marked *m*, is made to lift out with the core when it is taken from the box, and is withdrawn from the core afterwards. This core can also be made by turning it up on a core-barrel; but if this has to be specially made, it will be more economical to dispense with it and make a box like that described above.

XV.

PATTERN FOR A GUN-MOUNT PEDESTAL.

FIGS. 118–125 represent a pattern for the pedestal of a gun-mount. It consists of a socket combined with a flanged housing, by which it is secured to the deck of the vessel.

The top carriage, on which the gun is mounted, has a pivot on its lower side, and when the pivot rests in the socket of the pedestal the top carriage can be revolved in a horizontal plane.

Pedestals are subjected to very heavy strains, and their construction consequently must be reliable and solid.

Fig. 118 is a plan view, Fig. 119 a side elevation, Fig. 120 a longitudinal and Fig. 121 a transverse section of the pattern.

The flange, *a*, and the central body, or boss, for the socket, *b*, are the pieces first required when beginning the construction of the pattern. The former is built up with two courses of segments glued and screwed together. The latter, which is turned, is preferably made of thick material in order to have as few glue-joints as possible.

These pieces being prepared, the flange is secured to a surface board and the center piece, *b*, set up and secured in its proper position relatively to the flange. The housing, *c*, which surrounds the central boss

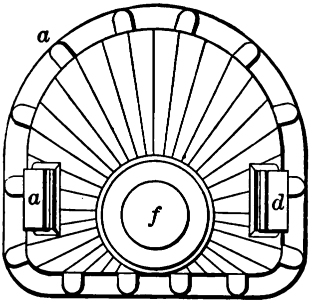


FIG. 118.

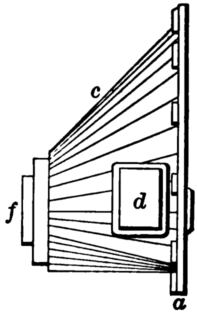


FIG. 119.

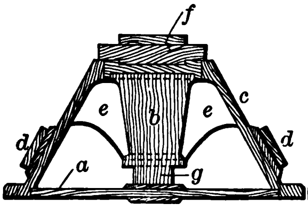


FIG. 120.

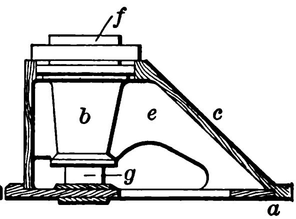


FIG. 121.

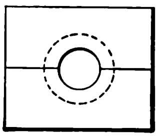


FIG 122.

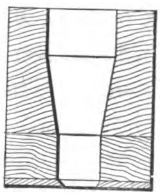


FIG. 123.

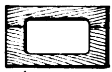


FIG. 124.

FIG. 125.

is then fitted to the flange at the bottom and to the boss at the top. The staves forming the housing are about four inches wide at their bottom ends.

Considerable work is involved in fitting and shaping the staves conformably with the different positions which they occupy in the housing. They are secured in place by glue and screws, nails also being used where necessary. When securing them in place three staves are closely joined and secured together, and then a joint is left open about one eighth of an inch. This is continued alternately around the pattern, to allow for the swelling of the wood while the pattern is being moulded, and has been found necessary in consequence of the great width made around the pattern by the staves.

The openings in the sides of the housing for the purpose of allowing access to the interior of the pedestal are formed with cores. Fig. 124 shows an end view and Fig. 125 a section of the box in which these cores are made. *d* and *d*, Fig. 120, are the core-prints for the location and support of these cores. The central piece, *b*, Fig. 121, and also the ribs, *e*, which connect the former with the housing, are arranged to lift out with the main core.

Fig. 122 shows an end view of the core-box for the socket, and Fig. 123 shows one half of the box as viewed from the inside. The prints for the support of the core are shown in *f* and *g*. The flange, *a*, Fig. 118, is made in two parts; the part projecting beneath the housing is made to separate from that outside of it, that it may be withdrawn from the mould independently of the remainder of the pattern.

In moulding, the pattern is first inverted and the main core made inside. This completed, the part of the flange projecting inside the housing is removed and the position of the pattern with the core is reversed. The mould is completed and the casting made in this latter position.

XVI.

PATTERN WORK FOR SCREW PROPELLER CAST ENTIRE.

When screw propellers are of large size and cast entire they are usually swept up in loam, but when the blades are made separate and are to be bolted to the hub, or when the screw is to be duplicated, a pattern of the blade is usually made and the moulding done in dry sand.

To construct the pattern of a screw-propeller blade attached to a hub is an interesting and instructive example of pattern-making. Working drawings of screws are made in different ways, according to the ideas of the draughtsman; one way has been described.

Figs. 126–131 show another method. Fig. 126 represents a plan and Fig. 127 an elevation of a right screw with two of the four blades broken off. These views are often assumed by the draughtsman to be all that is necessary in order to enable the pattern-maker to proceed with the construction of the pattern; but the developed sections should be worked out by the draughtsman. When they are not so done the pattern-maker may develop them himself. In this event, after receiving the drawing, the first thing he should do is to lay down full-size developed sections of the blade. These are readily determined in the following manner: Draw a line *ab*, Fig. 128, for a center line somewhat longer than the radius of the screw. With the radius of the screw and with one point of the trammel on the center line describe an arc equal in length to the fraction of the circumference occupied by one blade. Develop this arc into a right line at right angles to the center line, and from its extremities draw radii to the center from which the arc was described. Divide the center line into as many parts as it is desired to have sections of the blade (four are used in the illustration), and through the intersections draw lines at right angles to the center line and intersecting the two outside radial lines; the length of the lines between these intersections are those of the bases of the triangles *c*, *d*, *e*, and *f*, or periphery. The triangles are completed, Fig. 128, by erecting a perpendicular from the end of each base line. The height of these perpendiculars should be equal to the length of the screw, measured parallel with its axis. Now join the top of the perpendicular with the opposite end of the base line by a straight line for a right screw, as that represented.

For the purpose of laying down the thickness of blade at the different sections, as well as the parallel pieces with which the blade is built, it will be found convenient to arrange the triangles as shown in Fig. 129.

From a scale of thickness as that shown in connec-

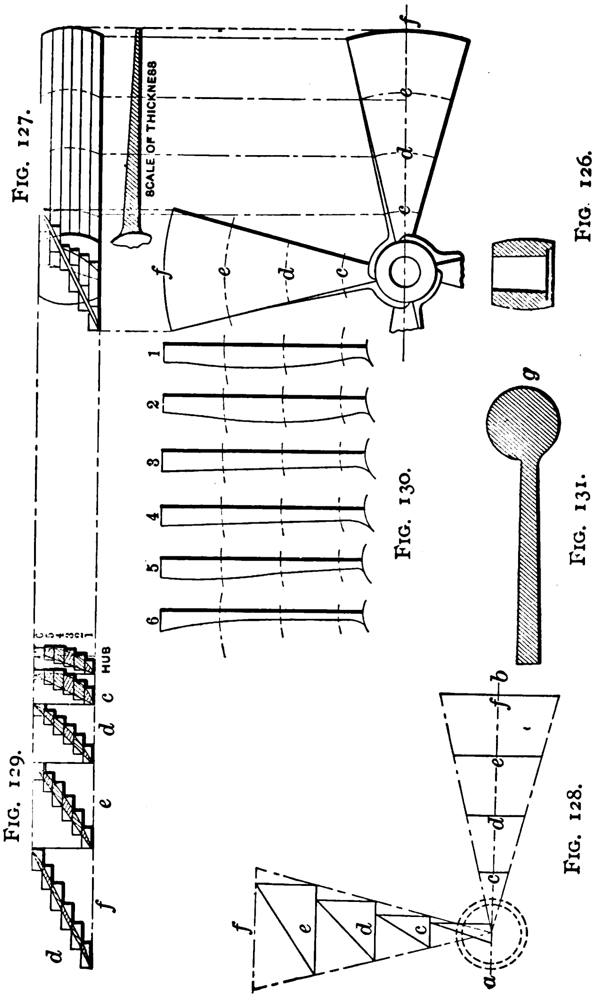


FIG. 126.

FIG. 127.

FIG. 128.

FIG. 129.

FIG. 130.

FIG. 131.

tion with the plan view, Fig. 126, which shows the thickest part of the blade at right angles to the face, take the thickness of each section, as *c*, *d*, *e*, *f*, and also at the hub. Lay it off at right angles to the center of the hypotenuse of the triangle corresponding in section. From the ends of each hypotenuse describe an arc the radius of which is equal to that of the edge of the blade. For each section describe an arc of a circle intersecting the arcs at the ends and the thickness dimension in the center of the hypotenuse, and the area thus inclosed will be the section of the blade at that part.

Now determine the thickness of the parallel pieces (Fig. 130), as 1, 2, 3, 4, 5, and 6, to be employed in constructing the pattern. This thickness may vary from $1\frac{3}{8}$ to $1\frac{3}{4}$ inches, according to the size of the blade. Draw lines through the sections of blade parallel with each other and perpendicular to the axis of the screw, with a distance between them equal to the thickness of the material adopted. From each intersection of those parallel lines with the lines bounding the sections of the blade through which they pass, other lines at right angles to them are drawn to the adjacent line, and thus a series of rectangles is produced which are the widths of the parallel pieces necessary to make the thickness at those parts.

When the screw is a true or right one, as that under consideration, the face lines of these parallel pieces are right lines radiating from the center of the screw, because a right screw is generated by a right line perpendicular to the axis radiating from the center and having a uniform axial progress while revolving. But all screws are not so made. The generating line is made of various forms and is set at different positions with the axis. It is also given variable as well as uniform axial motion while revolving. Sometimes the generating line is given the form of an arc of a circle described from the rearward of the axial line. In such a case the face line of the parallel pieces will be a spiral of increasing curvature toward the periphery. Then, again, the generatrix may be made a right line radiating from the axis, but having a less axial motion at the axis than at the periphery, producing a screw of diminishing pitch toward the axis. In this latter case when the pattern is built up of pieces of parallel thickness only, the center line between the extremities of the pitches will be a right line perpendicular to and radiating from the axis. With each succeeding piece forward of the center line the face line will increase in convexity, while for each succeeding piece aft of it the face line will increase in concavity and the face line would have to be worked out for each piece of parallel thickness.

In a case of this kind the construction of the pattern will be made easier by making the pieces tapering instead of parallel in thickness, reducing the thickness of each piece at the axis in proportion to the difference in the pitches; and then the face line of each piece would be a right line radiating from the axis.

The drawing is made convenient for building the screw with the face upward, and some workmen prefer doing it in this way; but the writer, who has had a very large experience in constructing patterns for screws, is decidedly in favor of making them face downward, as greater accuracy can be thereby attained.

All the necessary preliminaries to laying off the different pieces being completed and the material with which the blade is to be constructed prepared, it is only necessary to transfer the dimensions found to the pieces.

As the method is similar for all of the pieces, a description of the preparation of one will answer for all:

Select for No. 1, or bottom, a piece not less in width than the widest section on that line. Make one edge of it straight and square with the sides, lay off on it the several radii, as *c*, *d*, *e*, *f* (Fig. 126), and also the radius of the hub on that line. Beginning either with the hub or the peripheral end, with a pair of dividers step off the width of the section and transfer it to the arc of corresponding radius on the piece. Proceed in a similar manner for each succeeding section on that line. Tack a flexible batten on the piece with its edge passing through the intersections made on the arcs, draw a line along that edge, and work off the piece to that line square with its sides.

Grouped in Fig. 130 are shown the different pieces shaped and ready for building the blade.

A surface-board is necessary to insure satisfactory work. It should be lined off and the hub secured in its proper position upon it. The pieces are fitted against the hub. As the blade is to be made face upward, a guide secured at the periphery is necessary to insure the proper angle; props are also to be employed beneath the pattern to keep the pieces up to the guide, as there is a tendency of the pieces to depress on their overhanging side. Each piece, as the building up progresses, is set back on the piece below it and glued and nailed thereto, care being observed that the nails are out of the way of the tools in working the blade off. In the latter case it is only necessary to work down to the lines formed by the outside of the joints to obtain the required thickness throughout the blade. After the blade is worked off it can be made any desired shape within the limits of the pattern by laying off the outline and working off the surplus material, and easing off the back to suit the shape adopted.

When the screw is not very large the hub may be formed at the same time that the blade is being built up by laying off a section of the hub and blade on the same piece, as shown shaded by *g*, Fig. 131. But when the screw is of large size, it is more convenient to turn the hub separately and fit the pieces to it while building the blade.

Unless the screw is quite small, it is not necessary to make more of the pattern than one blade and the hub, as the pattern can be shifted around in moulding to make the required number of blades in the casting.

XVII.

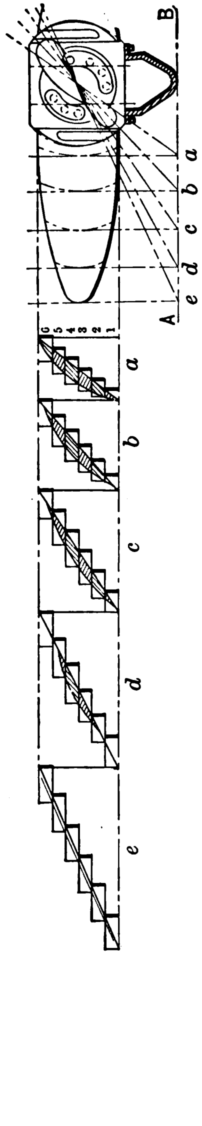
METHOD OF MAKING A PATTERN FOR A SCREW PROPELLER WITH SEPARABLE BLADES.

FIGS. 132–135 show a screw propeller different in shape from the one previously described. The views are numbered to follow consecutively those that have already appeared. The screw is a true one, that is, its pitch is uniform both radially and axially.

It will be observed that a blade developed on a plane is oval in shape, as shown in Fig. 132. The outer oval figure is intended to represent the shape of the blade as thus developed. Instead of the screw being cast entire the blades are made separately and provided with a flange for bolting them to the hub or boss. This is the type usually adopted for the propellers of ocean-going steamers. It possesses a distinct advantage when in need of repairs, for a broken blade can be renewed without removal of the screw from the vessel. However, a propeller of this kind is more expensive in first cost.

When a pattern is to be made of such a screw, and the drawing, as is generally the case, does not show the developed sections of the blade, these should be developed by the pattern-maker to full size. He should then determine the thickness of the material of which the blade is to be built and line off the sections with parallel lines according to the thickness adopted. It is well to dress up the lumber for the blade, rip it in pieces of sufficient size and allow it to stand until wanted for use. Next make two guide-frames, one to conform to the angle of the pitch at the hub and the other to the angle of the pitch at the periphery. As the blade pattern is to be made with the face downward, the angles of these guides will determine the proper helical form of the face of the blade. The method of making these guides has been explained.

A substantial surface-board is required. It should be somewhat longer than the radius of the screw, and in width a little greater than the length of base of the largest guide. On this board draw a line through it lengthwise for a center line. With the radius of the screw and with one point of the trammel on the center line describe an arc across the board, the arc at the center line being about five inches from the end of the board. From the same center with a radius equal to that of the hub describe another arc across the board. Step off the length of the base of the triangle *e*, at Fig. 133, the periphery of which will be equal to the length of the base of the largest guide. Transfer this length to the arc corresponding on the surface-board, making it equal on each side of the center line. From the extremities of



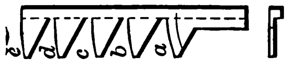


FIG. 134.

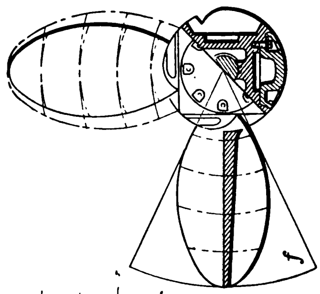


FIG. 132.

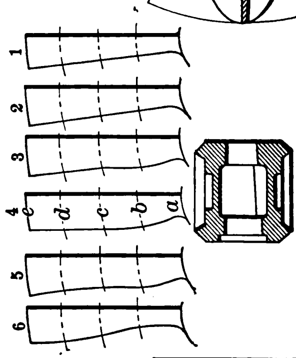


FIG. 135.

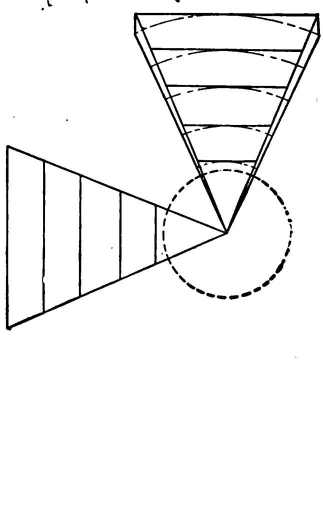


FIG. 133.

the arc draw radii to the center, and the sector thus formed will be that with which a plan view of the blade will agree when its top and bottom edges are perpendicular to the axis of the screw.

To determine the necessary length of the base of the guide when the outline of the blade is of special shape like that under consideration, it is necessary to lay down a projected view of the blade as viewed in line with the axis of the screw. Radial lines are then drawn tangent to the edges of the blade as at *f*, Fig. 132. The length of the arc at the periphery intersecting these lines is the fraction of the circumference the blade extends through and it is also the length of the base of the guide.

The two guides being prepared and having center lines drawn upon them, are to be secured to the surface-board, their center lines and curvatures coinciding with the arcs drawn on the board; the guide on the periphery being on the inside of its arc. A pattern for the flange by which the blade is secured to the hub is required. It is to be secured to the surface-board by brackets, being properly situated in relation to the face of the blade as determined by the guides.

To facilitate laying off the pieces for the blade a templet like that illustrated in Fig. 134 will be found useful. It is made of thin stuff equal in length to the radius of the screw. The arcs of the different sections, as *a*, *b*, *c*, *d*, and also those of the hub and periphery, are described upon it and enough of the templet cut away to admit of the arcs acting as guides while they are being marked on the blade pieces. The necessary preparations are now completed to allow the building of the blade to proceed.

It is not absolutely necessary with a blade pattern of this shape, where so much of it is cut away toward the periphery, to continue every piece to the outside guide. But the writer has found it good practice to do so. The small amount of material saved by stopping some of the pieces at the top and bottom short of the outside guide does not compensate for the extra care it involves to insure accuracy.

To begin the building of the blade pattern, select from the stuff previously prepared a piece of sufficient size to make the bottom piece marked 1, straighten one edge and make it square with the sides. Fit the straight edge of the piece against the guides with its side lying on the surface-board by beveling the edge where it comes in contact with the guides, being careful to have the bevels terminate exactly at the upper edge of the piece where it touches the guides. If it should occur in fitting a piece that the top of the bevel is carried in beyond the edge, the edge can be planed off until it coincides with the bevel. In this lies one of the advantages of fitting the pieces to the guides before reducing them to the shape in which they are built into the pattern.

Now mark the periphery of the blade on the piece which will be the outer edge of the outside guide; also mark the radius of the hub, which is the inside edge of the inner guide. Lay the templet on the piece, the marks for hub and periphery coinciding with those of the templet, and mark the arcs of the different radii *a*, *b*, *c*, *d*, etc. Take the widths of the piece 1 at the different sections and lay them off on the piece 1. On the arcs corresponding to the section draw a line through these intersections with the aid of a batten, work off the edge to this line square with the sides, place the piece on the surface-board where it was fitted against the guides, securing it there against shifting, but in such a manner that it may be readily released when desired. Proceed in a similar manner with piece No. 2, which, when prepared, secure on the piece No. 1 by glue, and with nails where they are not likely to come in contact with the tools in working the blade off. The remainder of the blade is similarly proceeded with until completed to the desired height. Where the parallel pieces come in contact with the flange they are fitting against it as well as against the guides. The shapes of the several pieces forming the blade are shown in Fig. 135.

After the pattern has been completed to the required height and before it is removed from the guides, it is to be roughly worked off on the back. Large, inside bevel gouges are useful for this purpose. The pattern is then to be turned over, with the face upward, utilizing the guides to hold it while the face is being worked off. When the face of the pattern is finished down to the lines formed by the joints of the pieces, the configuration of the blade is the next thing in order. This can be laid off directly on the face of the pattern, or a templet of

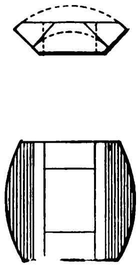


FIG. 136.

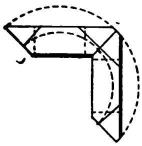


FIG. 137.

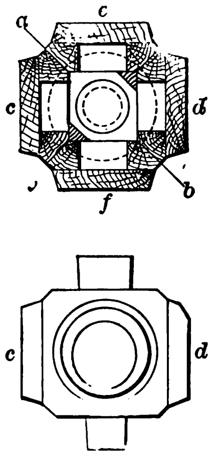


FIG. 138.

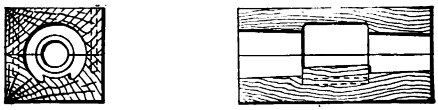


FIG. 139.

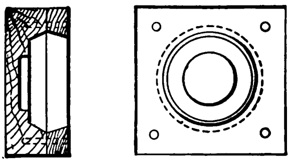


FIG. 140.

FIG. 141.

the shape can be made of stiff paper and the pattern marked by it.

The shape of the blade being lined off on the face of the pattern, the surplus material outside of this boundary is to be removed. This accomplished, the face is given a coat or two of shellac and the pattern turned with its face downward and its back worked off down to the lines formed by the joints of the pieces of which the pattern is composed. The edges are next to be finished by working off the back to an easy curve where it trends toward the face.

When building up the blade it is well to avoid gluing the flange to the blade pieces. By arranging the flange to be removed while the blade is being worked off the latter is accomplished much easier.

After the flange has been secured permanently to the blade, the fillets where they join are completed. The fillet on the back may be worked on the pieces which compose the blade, but the fillet on the face is best fitted separately.

After being sandpapered and receiving several coats of shellac, the pattern is ready to be moulded.

Glue alone should not be depended upon to hold the pattern together while being moulded. Brads should also be freely used for the purpose.

Fig. 142 shows a partly built-up blade pattern. It differs in shape from those shown in the drawings. For the purpose of making prominent the manner in which the pieces of parallel thickness are fitted upon each other and to the guides they are shown somewhat disproportionate in thickness.

Figs. 136–141 show the method of constructing the pattern for the hub, or, as it is termed in England, the boss, which is generally moulded in loam when very large. When so moulded the pattern is

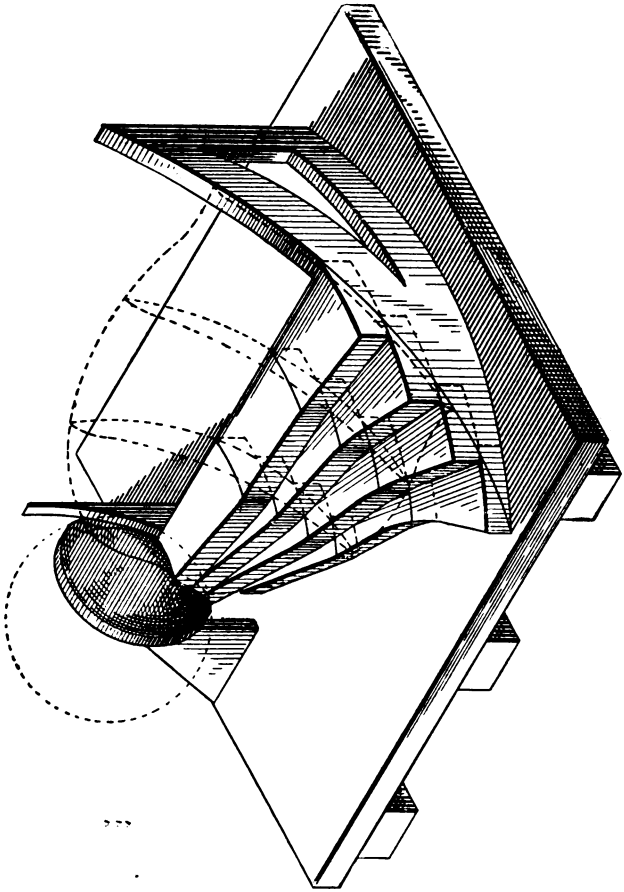


FIG. 142.

made a model of the casting, but so constructed that it can be taken apart to permit of its withdrawal from the mould and the release of the interior parts or cores which have been made in the course of moulding it.

When the hub is of moderate size it is best moulded in dry sand. In this case it is first constructed in the form of a box which separates or parts diagonally across its ends. To form the sides four frames, as in Fig. 136, are made of stuff sufficient in thickness to allow of their being worked to the required spherical form. Each frame is made of four pieces. When these are joined together, they leave an opening in the middle of the frame which is covered by the core-print for that core which forms the recess in the side.

The frames are fitted together with miter-joints (see Fig. 137). They are secured in pairs, each pair being glued and nailed together where they unite. The ends of the box, which are square in shape, are made in two pieces parting diagonally across the square. After these are secured to the sides corner blocks are glued and nailed inside the box to strengthen it at the corners where it is liable to be reduced to small thickness in being worked to the spherical form. Previous to securing the frames together their mitered ends are marked off by a templet having the radius of the hub, and the material outside of this line is worked off square with the joint. When the four frames are put together the outline of the miter joints gives the shape to which the pattern is to be worked in reducing it to the spherical form. The spherical form can be obtained either by turning in a lathe or by working the pattern off by hand.

The writer has employed both methods, but prefers the latter when the pattern is to be moulded in dry sand and cores are used to form the interior of the mould.

After the spherical form has been given to the pattern it is ready for the core-prints. The prints *a*, *b*, Fig. 138, for the tapered core which forms the shaft-hole are secured permanently to the pattern; but *c*, *d*, *e*, *f*, on the sides, for the cores which form the recesses where the blades are secured to the hub, are made removable. They are held in place by draw-pins, which are withdrawn while the pattern is being moulded, thus releasing the prints from the pattern and allowing the latter to be drawn from the mould first and the prints afterwards.

The recess cores are inserted from the inside of the mould previous to setting the main core, and are secured in the impressions made for them by the prints.

Fig. 139 shows a longitudinal and transverse section of the box for the core which forms the hole for the shaft through the hub. When but one casting is needed a half-box can be made to answer; but when several castings are required it pays to make a whole box.

Fig. 140 shows a plan and a section of the box for the core which forms the recesses in the sides of the hub where the blades are bolted to it. Fig. 141 shows a plan and a section of the box for the core which forms the recess in the flange of the blade.

XVIII.

CONSTRUCTION OF SMALL SCREW PROPELLERS.

In constructing small screw propellers, unless special precautions are taken in view of the frailty of the pattern, much difficulty will be encountered in making it retain its shape while being moulded. In moulding a wooden pattern of this kind it becomes necessary to provide a block or follow-board for the support of the pattern while the mould is being rammed up. This block is sometimes made of plaster of Paris, its form being obtained from the pattern itself.

In an establishment where many patterns of small screws of various forms were made, and where different methods of making and moulding such screws were tried, that which insured the greatest satisfaction was first to make a block of wood whose helicoidal face represented the equivalent of the screw desired. Upon this block the pattern for the blade was built of alternate pieces of pine and baywood. The block was afterward employed to support the pattern while being moulded. This method has special merit when the screw is of peculiar form and a correct casting is desired. By this method, also, the moulding is done with green sand in a core-box, a pattern of but one blade being necessary in order to obtain as many blades as may be required in the casting. It also insures the casting of all blades as nearly alike as it is practically possible to make them, and secures uniformity throughout the casting—which is very important when experimental data are desired.

Fig. 143 shows the first step of the process, namely, that of making the block. This is made of about 2½ inches greater radius than that of the pattern to allow for the joint of the mould. It is not necessary to make the block of the full dimensions of the box, but merely of sufficient width and depth to admit a joint around the outside of the pattern of the blade. If the screw is to be a true or right one, as that illustrated, the block should be built up of pieces of equal thickness, the edges being straight and radiating from the center. Given the diameter and pitch of the screw, the first thing is to lay off a developed diagram of the periphery of the block, from which diagram are to be determined the thickness and width of the pieces that will constitute the block.

Suppose a true screw, of four blades 30 inches in diameter and 45 inches pitch, is required. Adding 2½ inches to the radius for the joint of the mould will make the block 17½ inches radius. One fourth of the corresponding circumference will make the base of the triangle 27½ inches, and one fourth of the pitch will give an altitude of $11\frac{1}{2}$ inches. Dividing this last by ten will give $1\frac{1}{8}$ inches, the thickness of the pieces. Dividing the base by the same number gives $2\frac{3}{4}$ inches as the distance on the periphery that the edge of each piece must be set back of the piece below it when building up the block from the bottom. When preparing the pieces it is advisable to make them somewhat wider than their finished widths, as by so doing the joints can be more easily made. The surplus material may be removed after the block has been worked off.

In building the pattern of the blade it is advisable to have the two outside edges of baywood. Beginning at the bottom, which will be the after edge of the blade, a piece of baywood is fitted to the block and tacked thereto in its proper position. A piece of pine is next fitted to the block, and, to make a close joint with the baywood strip to which it is to be glued, this pine piece is also tacked to the block. The other pieces which go to form the blade are prepared in a similar manner. As each piece is fitted, the thickness of the blade at that part is laid off on it and the back of the piece is chamfered to the line. The thickness can be obtained by laying down the sections of the blade as shown in Fig. 152. In order not to have the pieces too thin (in which case it would be more difficult to make good joints) it is advisable to shape the pieces as shown in Fig. 152. In this sketch the lower parts of the sections of the blade are shown built up with pieces somewhat thicker than the finished dimensions, with

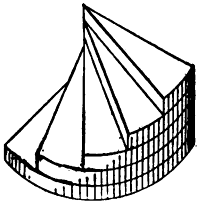


FIG. 143.

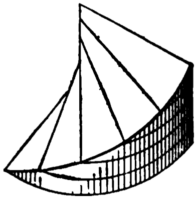


FIG. 144.

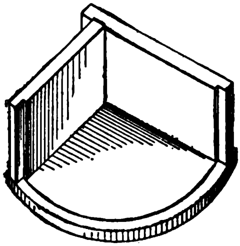


FIG. 145.

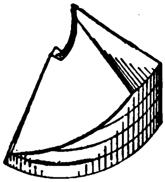


FIG. 146.

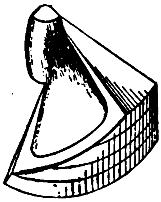


FIG. 147.

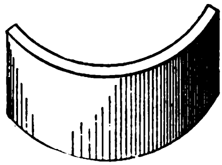


FIG. 148.

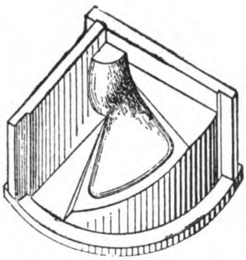


FIG. 149.

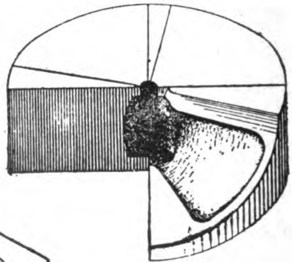


FIG. 150.

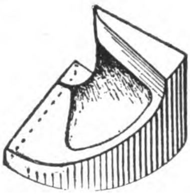


FIG. 151.

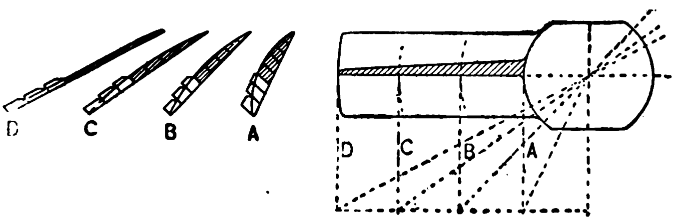


FIG. 152.

one of their sides chamfered to the finished line. The upper parts of the sections are represented as when reduced to finished size.

When all the pieces forming the blade are glued together and sufficiently dry, the pattern is removed from the block, its face smoothed, the outline of the blade laid off and the edges worked to the line. The back of the pattern is next worked off, and the whole then finished with shellac, when it is ready to be fitted to the hub. If preferred, the section of the hub can be fitted in its place on the block, and the pieces forming the blade fitted on at the same time that they are being fitted to the block. There is little choice, however, between the two methods. The blade is to be secured to the hub by glue and screws. Sufficient margin for the joints of the mould is to be laid off on the block outside the blade, and the surplus material of the block removed. The pattern will then be prepared for the core-box. This is made four or five inches deeper than the block and pattern, and should be made to be taken apart, as in Fig. 145. The angle of the core-box is made according to the number of blades required in the screw. For a three-bladed screw the box will extend through 120 degrees; for a four-bladed screw, through 90 degrees, etc. The box should be made of two-inch material, put together with screws, and the outside or circular end so arranged as to admit of easy removal.

Before beginning the mould, it is necessary to provide a skeleton of cast iron for building in the cores for the drag parts of the mould, and skeletons also for the copes; all these should be provided with suitable lifters.

When beginning the mould, the block with the pattern being in the bottom of the box, the remainder of the box is rammed up with green sand, the skeleton having been properly placed in the mould during the operation. The drag being completed, the box is inverted and the block which supported the pattern removed, leaving the latter in the mould. The parting having been prepared and the gates and risers properly arranged, the operation of ramming up the cope is proceeded with. The skeleton for the cope should not only have lifters, but be provided with prickers or wires extending to within a half-inch of the pattern and joint of the mould. The purpose of these is to support the sand. The cope being completed, the sides and end of the box are removed, the cope lifted off and held suspended, the pattern withdrawn, and the mould dressed. A bed having been prepared, the drag is lifted from the bottom board and placed on the bed and the cope placed upon it. One fourth of the mould is now complete, as illustrated in Fig. 150. In the same way the other sections of the mould are prepared. When all parts of the mould are in place they are weighted with plates made for the purpose and conforming in shape to the sections of the mould. A curb of thin boiler-plate bent to a circular shape, with flanges turned outwardly and radially for bolting together, is made to encircle the mould. The space between the mould and the curb is rammed with sand, and after the pouring-gate is prepared the mould is ready to be poured.

In making the core-box it is advised that it be made of sufficient radius to answer for the largest screw likely to be wanted. Screws up to four feet in diameter have been successfully made by this method. When small screws are to be duplicated it is best to have a metal pattern and do the moulding in a flask. The metal pattern can be advantageously made, as the foregoing explains.

Figs. 153–156 illustrate a pattern of a globe valve. This is selected from correspondence because it furnishes an excellent example of making what is regarded a difficult pattern. Fig. 153 shows one half of the pattern, which serves the purpose of elucidation, the other half being of course the counterpart of that shown. The two pieces comprising the half-pattern are glued together on the line *MN*. Both of the pieces can be turned in a lathe, the only hand work necessary being the squaring of the core-prints *BB* and cutting the hexagon *DD*.

Fig. 154 shows one half of the main core-box; both halves are counterparts and are doweled together with the pins *EE*; the spherical part is turned out in a lathe.

Fig. 155 shows a block made to fit the slot *F*, Fig. 154, and which aids to form the circular wall around the valve-seat as well as the hole through

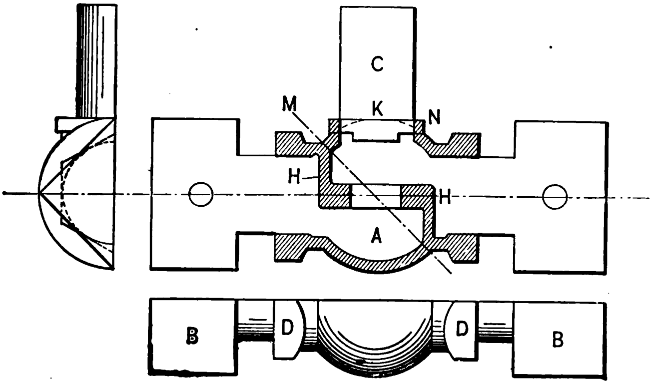


FIG. 153.

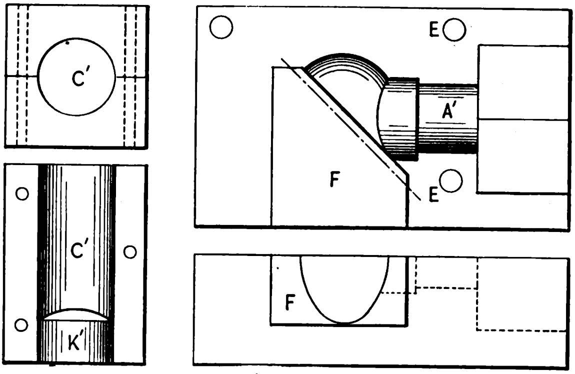


FIG. 154.

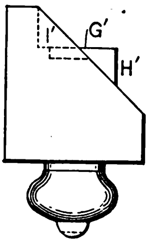


FIG. 155.

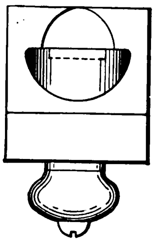


FIG. 156.

the seat *G*. The boss *H* is turned to the radius of the outside wall *H*, Fig. 153, while the groove *I* forms the core for the inside wall. A handle is fitted to the block by means of which the latter can be drawn out of the way before the core-box is separated. Two cores from this box are required for each mould. A straight round core made by the box Fig. 156 is for the stem end. The end of this core fits against the spherical surface of the main core at *K*, Fig. 153. To accomplish this a plug *K′*, with a spherical surface to match the main core, is fitted into the end of this box.

XIX.

PATTERN WORK FOR MOULDING A LARGE BELT-PULLEY OR FLY-WHEEL.

A COMPLETE pattern for a large belt-pulley or fly-wheel is now never made to obtain a casting therefrom, but recourse is had to expedients involving a comparatively small amount of pattern work. The pattern work to obtain such a casting consists of a former for the outer wall of the mould, a core-box for the arms, a core-box for the center core, and two core-boxes for covering cores.

In beginning the mould the first pieces required are the former for the outside wall, shown by *a* and *b*, Figs. 157 and 158, respectively, and the center pin *o*, Fig. 158.

The former requires to be substantially made and consists chiefly of a base-board having a hole to suit the center pin, and a segment whose convex side is worked off to the radius of the exterior of the rim of the wheel. The segment is secured to the base-board and braced thereto in order to maintain a concentric position with the center and a right angle with the face of the board. *o* shows the center pin about which the former re-

FIG. 157.

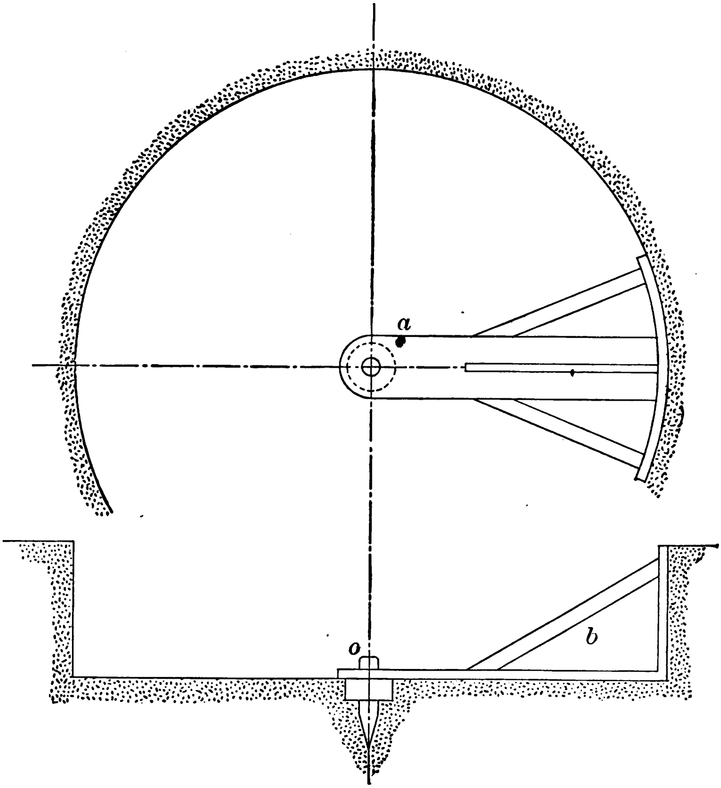


FIG. 158.

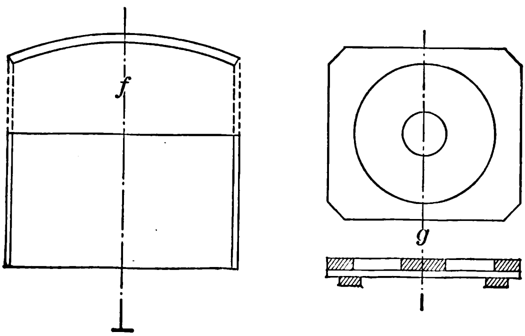


FIG. 159.

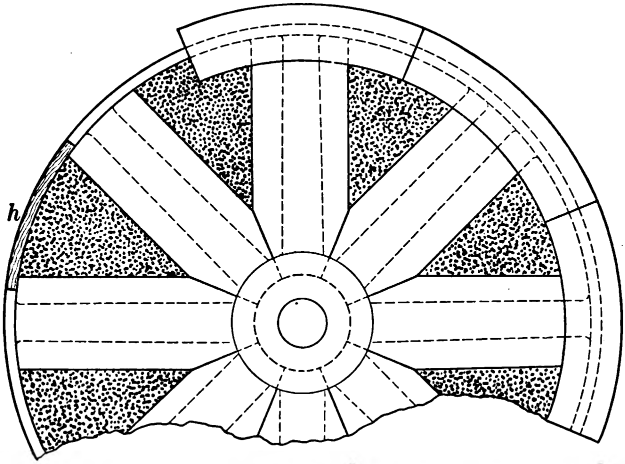
volves. In Fig. 159 *f* shows a plan and elevation of a segment of the rim, and *g* shows a plan and section of the core-box for the core which covers the center or hub opening of the mould.

In Fig. 162 *c* shows a plan and section of a core-box containing a pattern of one half of an arm of the wheel. Two cores from this box are required for each arm. *e* shows a plan and section of the core-box for the cores to cover the rim opening of the mould. These comprise all of the pattern work necessary to enable the moulder to complete the mould.

In beginning the mould, a level bed is first prepared and the center pin, *o*, Fig. 158, is located and fixed in place. The former is centered on the pin and the building of the outer wall of the mould proceeded with by ramming green sand against the former and striking it off level with the upper edge of the segment. This completed, the former is moved around about two thirds of the length of the segment and the outer wall extended by repeating the previous operation. The wall is continued in this manner until the entire circle is covered. The outer wall being completed, the mould is lined off according to the number of arms the wheel is to contain. The mould is then ready to receive the cores. It is assumed that the cores have been made in the mean time, while the mould was being prepared to receive them.

The cores for the arms are the first required. The segment *f*, Fig. 159, is placed in the mould in the position shown by *h*, Fig. 160, and the bottom

FIG. 160.



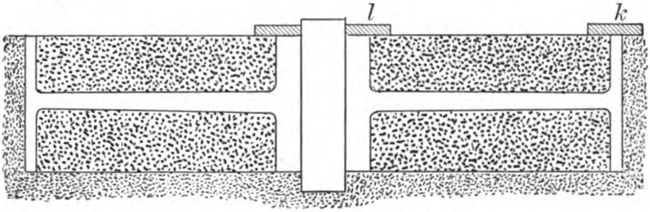


FIG. 161.

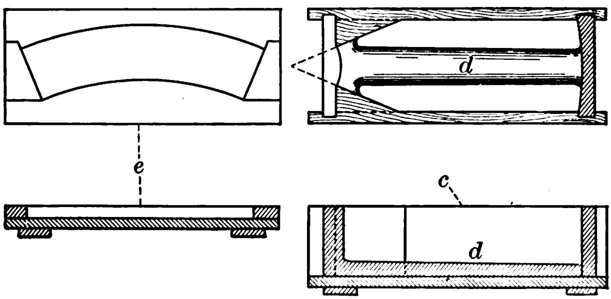


FIG. 162.

half of an arm core is set radially according to the line prepared for it, with its outer end against the segment which gauges the thickness of the rim. The upper half of the core is then placed upon the lower. This operation is repeated until all of the arm cores are placed, Fig. 160. The spaces between the cores are filled in with green sand, the segment being used to stop off the sand, and this completes the inner wall of the mould. The center core for the hub, which is a plain cylindrical one, is set, and the covering cores from box *g*, Fig. 159, placed. The covering cores from box *e*, Fig. 162, are next placed over the rim opening.

The gates and risers having been provided for through the covering cores, the mould is weighted, and the top built up with green sand to the height necessary for the runners, gates, vents, etc. This completed, the mould is prepared to receive the metal.

XX.

PATTERN FOR AN OBLIQUE CHUTE.

PATTERN-MAKERS occasionally meet with problems that are exceedingly perplexing, especially to those who have neglected the study of geometry; moreover,

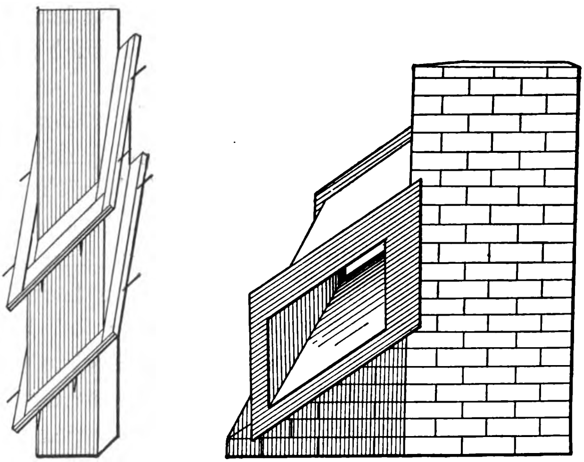


FIG. 163.

such problems are often by no means easy to solve even by those fairly informed in that science. Fig. 163 shows the pattern and casting which are the subject of one of those problems. A cast-iron chute rectangular in section is required to pass in an oblique direction through a brick wall 17½ inches thick. It passes through at an angle of 35 degrees with the perpendicular and 45 degrees with the face of the wall. As the illustration shows, the chute emerges from the wall with its sides parallel with the vertical joints of the brickwork, but its top and bottom are oblique to the horizontal joints of the wall. This obliquity results from the combination of angles and the rectangular section of the chute. There are several ways of determining the length of the pattern and the angle of its ends in such a case, and two of these ways will be described.

In order to obtain the proper dimensions and angles of the pattern it is advisable to lay down full size the necessary views, as illustrated in Fig. 164. First draw the plan *A*, making *a* equal to the thickness of the wall and *b* equal to the base of the required triangle horizontally. In this case the horizontal angle being 45 degrees makes both sides of the triangle 17½ inches. Draw the line *d* parallel with the hypotenuse *c* and make the perpendicular distance between the two lines equal to the external width of the chute, 14 inches, and extend *d* to *e*. Draw the side elevation *B* equal to the thickness of the wall, making the line *f* 35 degrees with the perpendicular. Project a line from *g* toward *h* and extend it indefinitely. Project the point *i* toward *k* and extend it indefinitely. Project the point *l* and intersect *ik* at *k*; connect *km*: this line will give the angle of the chute through the wall when viewed in front elevation. Project the point *e*, and intersect the line *gh* at *h*. Project the point *n* toward *o* and extend it indefinitely.

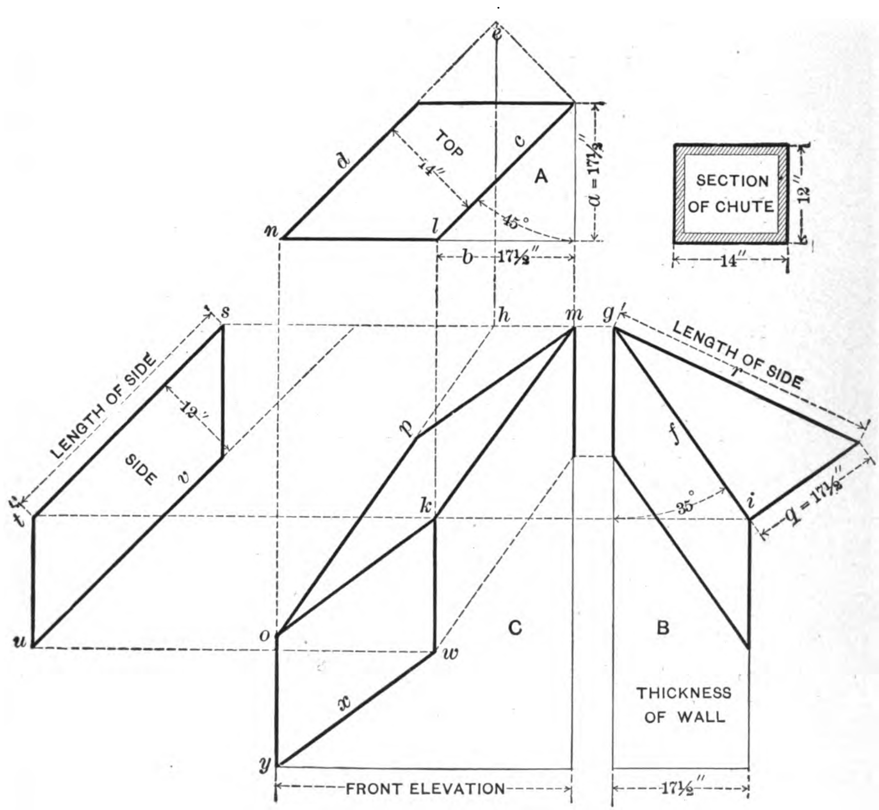


FIG. 164.

From the point *h* draw the line *hp* parallel with *mk*, intersecting *no* at *o*; connect *ko*, and the length of the line so formed will equal the length of the angular side on the top and bottom of the chute at its ends. So far, while we have arrived at the width of the chute, as well as the angle of the ends on the top and bottom, there is no line that gives the actual length of the chute, because to obtain that it is necessary to have a view from a point perpendicular to the side: the side being obliquely viewed in that which has been drawn. The actual length of the chute through the wall is the diagonal line, or hypotenuse of the angle whose sides are the line *f* and the line *q*. Draw *q* perpendicular to the end of *f*, making the length equal to the thickness of the wall, connect the extremities of *f* and *q*, and the hypotenuse *r* will equal the actual length through the wall and between the flanges of the chute; this line also furnishes the basis for obtaining the angle of the ends of the chute on its sides. With the length of the line *r* intersect *gh* at *s*, and *ik* at *t*, and draw *tu* parallel with *no*. Draw *v* parallel with *r*, making the perpendicular distance between the two lines equal to the external thickness or depth of the chute. Let *v* intersect *tu* at *u*; the length *tu* will then equal the depth of the end of the chute where it emerges from the wall, and the angle so formed will be the angle of the ends on the side of the chute. Project and make *kw* equal to *tu*; from *w* draw *x* parallel with *ok*, intersecting *no* at *y*, and the rhomboid so formed by *ko* and *wy* will be the figure of the end of the chute, minus the flange, when viewed perpendicular to the end as it emerges from the wall. Having determined the most important part of the problem, and proper length and angles for the pattern, its construction is not difficult. The pattern complete except the core-box, which is a plain rectangular one, is shown at the left in Fig. 163.

To begin the pattern a box or core-print whose cross-section equals that of the interior of the chute is built up of one-inch material; the length of the print is sufficient to allow bearings for the core beyond the flanges at each end. Upon the print the length and angles of the pattern are lined off and the thickness for the metal is added on in conformity with the lines. Where the thickness forms undercuts, as at one end of the sides, the undercut pieces are made to be drawn separately from the body of the pattern; they are secured in place by draw-pins. After the thickness is completed the flanges at the end are fitted to the pattern and secured by draw-pins; they remain in the sand and are drawn out after the body of the pattern has been lifted from the sand.

Another way which the writer has often used with great advantage and unvarying success in working out difficult problems of this character is to make a wood model to a convenient scale and develop the object from it. He would especially recommend this method where a number of different angles are involved, because it enables one to comprehend the problem more readily by having the chief features of the object under view, thereby impressing them more deeply on the mind and making mistakes less liable.

Fig. 165 shows a model of all that is necessary to solve the present problem, and in making the pattern it would save tenfold time spent in making the model. It is not necessary that such models should be very elaborate, but accuracy is abso-

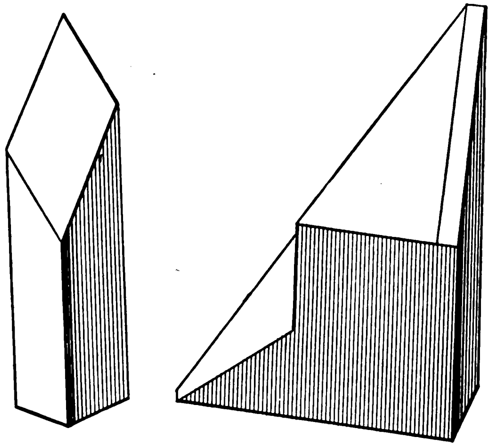


FIG. 165.

lutely essential. It so happens in this case that the angles of the ends of the chute agree with those with which it passes through the wall, 35 degrees and 45 degrees, or so near to them that they answer practical purposes; but this result does not follow as a rule for any combination of angles.

A problem of the foregoing character was once submitted to the author after its solution had baffled the efforts of several excellent draughtsmen for a number of days, and he solved it with the aid of a model which required less than two hours to make.

XXI.

PATTERNS WITH BRANCHES.

FITTING branches to patterns, such as pipes and valves, by the usual cut-and-try method is tedious and consumes unnecessary time, especially when the body to which the branch is to be fitted is of some peculiar form. By preparing paper patterns of the line of juncture of the two parts, and marking this line off on the branch, the work is more skilfully performed and the job expedited. Several different forms of preparing these patterns are here elucidated. When the principles involved in these problems are mastered, they can be applied to a wide range of work.

When the body and branch are of equal and uniform diameter, it is simply necessary to first cut the end of the branch on either side at 45 degrees with the center line, as at *A* in Fig. 166. The line so produced on the circumference of this branch will be that of its juncture with the body, and when the branch is cut across to this line it will fit the body if the work is accurately performed.

B presents a problem not so simple as the previous one. Here the branch is smaller in diameter

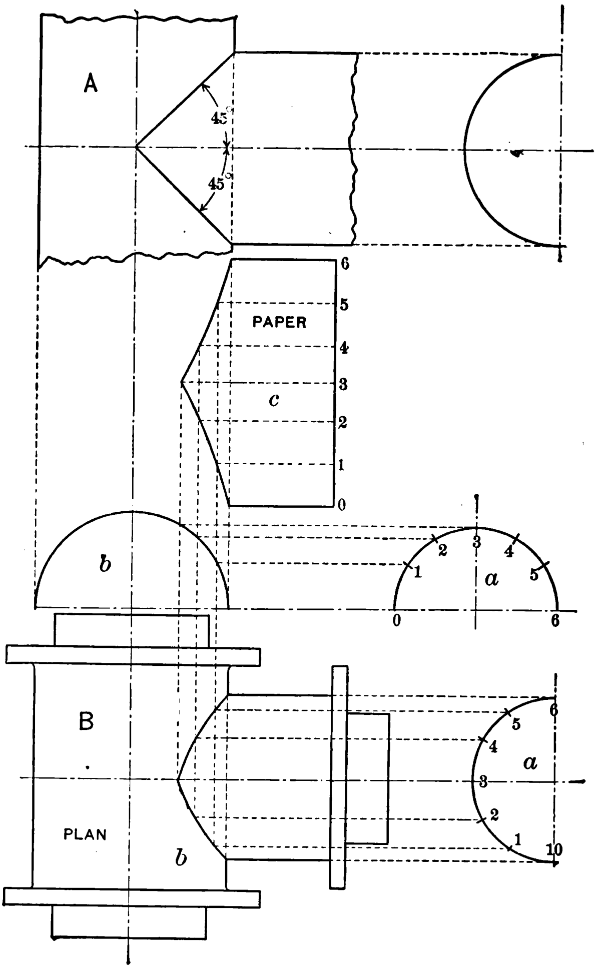


FIG. 166.

than the body to which it is to be fitted, and a paper pattern is to be made to mark off the line of juncture. Lay down a plan and a section of one half of the body and branch, as *a* and *b*; divide the semicircumference of the branch *a* into any number of equal parts, so as to have a line in the center, and number the intersections. From these intersections project lines intersecting the curve of the body *b*. Now tack down a piece of suitable paper, *c*, in the position shown, and on it draw two parallel lines, as 0 and 6, whose distance apart is equal to the circumference of half the branch *a*. Divide this distance into the same number of parts as that of *a*, and draw lines parallel with the outside lines. From the intersections of the lines from branch *a* with the body project lines intersecting the lines on the paper *c* with corresponding numbers. A curve drawn through these intersections will give the developed curve of juncture of the branch with the body, and as in this case both halves of branch are alike, the pattern will answer for both. To arrive at this developed curve it is not absolutely necessary to lay down the plan view when both the branch and body are cylindrical and are at right angles; but when it is desired to show the projected curve of the juncture, the plan view is necessary, and the intersections for it are obtained by projecting from the sectional views, *a* and *b*, to ordinates with corresponding numbers on the plan.

Fig. 167 shows a branch fitted diagonally to the body of the pattern. To obtain the developed curve in this case the method to be pursued is similar to that in the previous problem. The plan and sectional views are to be made and divided as previously

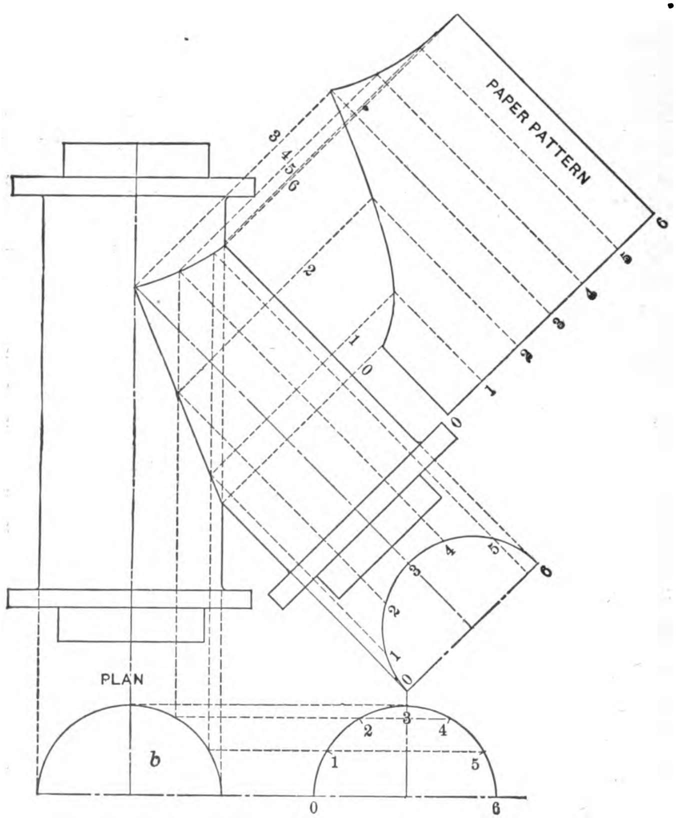


FIG. 167

explained, and the projected curve of the juncture of the body and branch obtained by projecting from the intersections on the section *b* of the body to ordinates correspondingly numbered on the plan view of the branch. The developed curve of the juncture is then obtained by placing the paper alongside of the branch and projecting from the latter. Lay off on the paper two lines parallel with each other, and with the axis of the branch make the distance apart of the lines equal to the circumference of one half of the branch, and divide this distance into the same number of equal parts as that of the branch. From the intersections which produced the projected curve of juncture of the branch with the body on the plan, project lines at right angles to the axis of the branch to the ordinates on the paper, intersecting those correspondingly numbered. A curve drawn through these last intersections will give the developed curve of juncture.

Fig. 168 illustrates the body of a pattern which is not cylindrical, but which has a cylindrical branch fitted to it. With many workmen, at first sight, it would seem a very difficult problem to work out the developed curve of juncture of branch with body in this case, but if the previous examples have been studied and mastered, it will be found quite an easy matter to do so.

The plan view is to be first laid down, or so much of it as is covered by the branch. Draw a section of one half of the branch in the position shown by *a*, and divide its circumference as in previous examples. Through these intersections draw lines parallel with the axis of the branch, extending across the body, thus cutting the body into as many sections as lines.

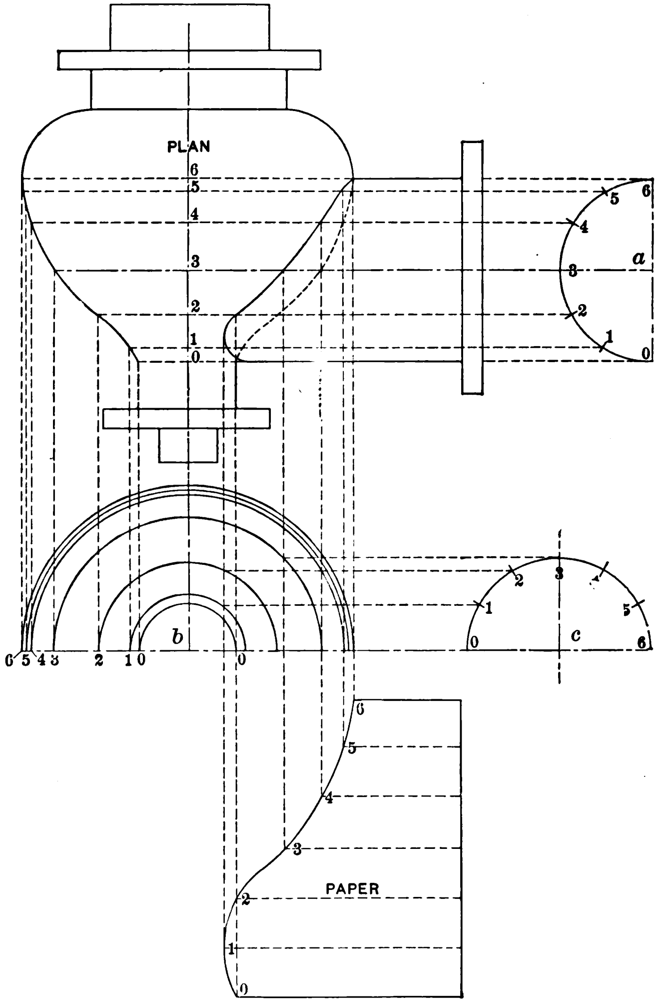


FIG. 168.

These sections of half the body are to be drawn below the body in the position shown by *b*, and numbered correspondingly to those on the body. A section of the branch is drawn in the position shown by *c*, and the half-circumference divided the same as that for the plan view. From these intersections lines are drawn intersecting the sections of the body correspondingly numbered. From these last intersections both the developed and the projected curve of juncture are obtained by following the method of doing so explained in the previous examples.

It is sometimes required to fit a branch or boss on a body away from the center line of the latter. Fig. 169 shows two such cases. In the upper view, *A*, the branch is at right angles to the body and to one side of its center. To obtain the developed curve of the juncture of the branch with the body in this case lay down the branch and so much of the body as necessary in both end and side views. Draw end views of the branch and divide them into equal parts; from these intersections project lines parallel with the axis of the branch and intersecting the body. Number these ordinates correspondingly. Tack down the paper in the position shown and draw two lines parallel with each other and with the axis of the branch; make the distance apart of the two lines equal to the circumference of the branch. Divide this distance into the same number of equal parts as the end view of the branch, and draw ordinates parallel with the outside lines. Number the

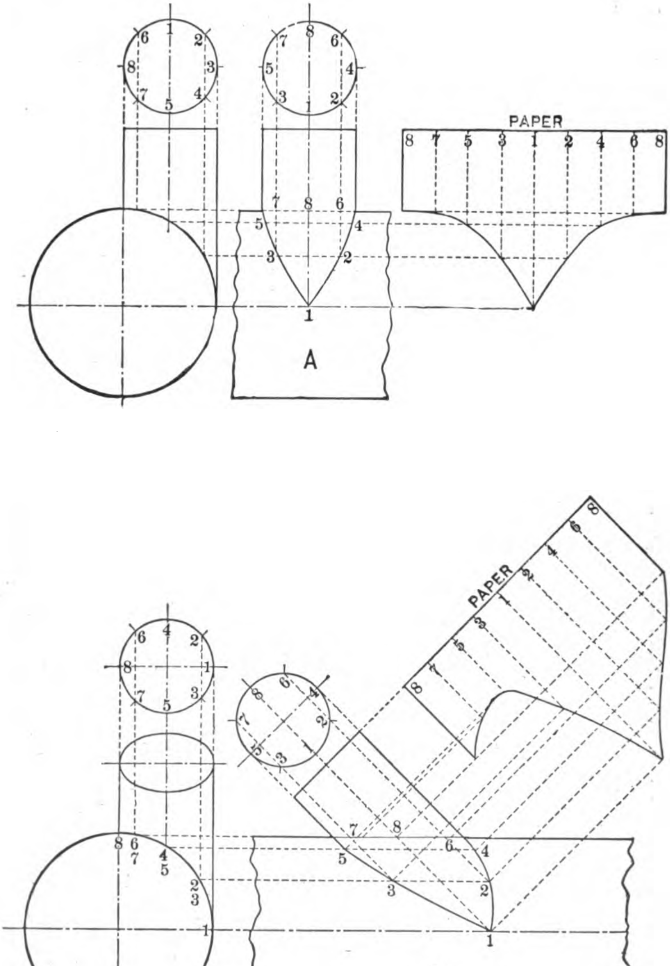


FIG. 169.

ordinates to correspond with those projected from the end view of the branch. From the intersection of the ordinates on the branch with the body project lines intersecting the ordinates correspondingly numbered on the side view and on the paper; a curve drawn through these intersections on the side view will give the projected curve, and a curve drawn through the intersections on the paper will give the developed curve, of the juncture of the branch with the body.

The lower view, *B*, shows the branch located to one side of the center of the body as in the previous case, viewing the body on the end; but viewing the body on the side, the axis of the branch is inclined to that of the body.

To obtain the projected curves of juncture in this case draw the two views as before and draw ordinates on the branch projected from intersections on its end view. From the intersections of these ordinates with the body on the latter's end view project lines intersecting the ordinates correspondingly numbered on the side view. A curve drawn through these latter intersections will give the projected curve of juncture of branch with body. To obtain the developed curve tack down the paper in the position shown, and upon it draw two lines parallel with each other and with the axis of the branch on the side view, making the distance between the lines equal to the circumference of the branch. Divide this distance into the same number of equal parts as the branch, and draw ordinates parallel with the two end lines. Number the ordinates to correspond with those on the branch. From the intersections of the ordinates on the branch with the body, as shown in the side view, project lines at right angles with the axis of the branch intersecting ordinates correspondingly numbered on the paper. A curve drawn through these last intersections will give the developed curve of the juncture of the branch with the body.

Where there is frequent occasion for fitting branches when making plain patterns, such as pipes, etc., a device like that shown in Fig. 170 will be found a great advantage. It consists chiefly of a base-plate having a true surface, with a spindle fixed near one end and perpendicular to the true surface of the plate; also a head which has both a sliding and a revolving motion on the spindle. The sliding head carries a radius-bar set at right angles to the axis of the spindle. The radius-bar is adjustable to suit different radii, and one end is provided with a scriber held in a clamp bearing so that it can be adjusted to suit different diameters of branches.

A and *B* are cradles to which the work is secured by wood-screws while being operated upon. The cradles can be made of wood, but are much better when made of metal and finished accurately. There should be a center line scribed on the surface of the base-plate parallel with its sides and intersecting the axis of the spindle to serve as a datum line for setting the cradles when the work is to be marked.

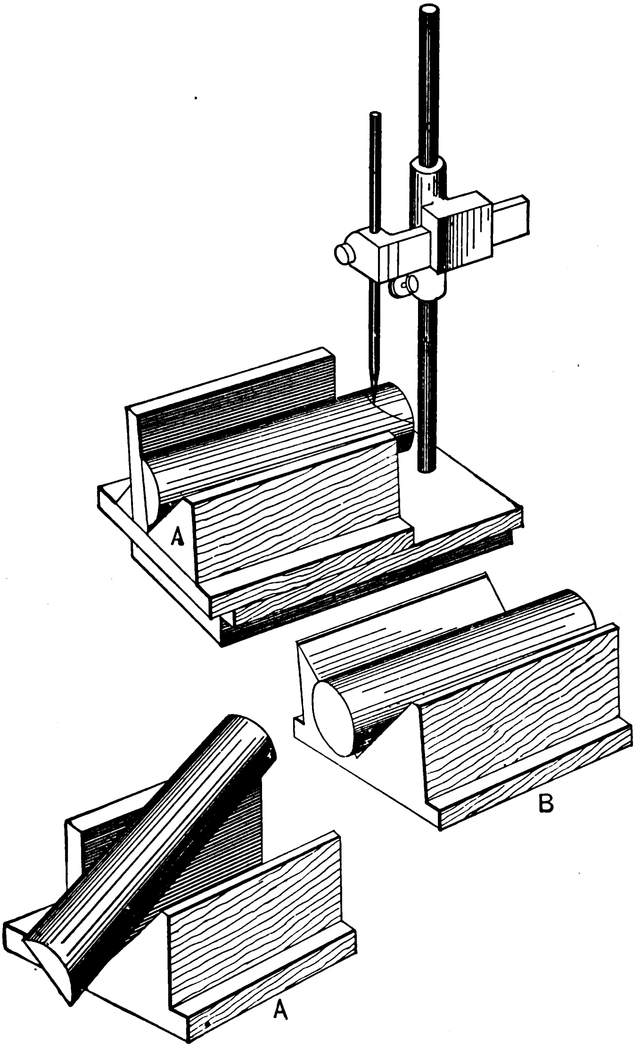


FIG. 170.

The cradle *A* is intended for parted work, and *B* for work not parted.

The device is equally handy whether the boss or branch is set at right angles to the body of the pattern or at any other angle, or whether it is to set away from the center line of the body. In the former case it is only necessary to secure the work at the desired angle in the cradle, or, where it is set to one side of the center line of the body of the pattern, to set the cradle accordingly on the base-plate while the curve is being scribed on the work.

After the work is scribed, which will be on the upper side as it sets in the cradle, the latter can be taken to the band-saw and the work cut to the line. If the entire operation has been carefully and accurately done, the branch will need very little further fitting to allow it to be secured in the place intended for it.

XXII.

TEETH OF GEAR-WHEEL PATTERNS.

THE increasing use in machine construction of cut gear and also of machine-moulded gear has somewhat lessened the extent that gear-wheel work formerly held in the trade of pattern-making. But notwithstanding this tendency gear-wheel work is still a very important factor in the trade of pattern-making because of the skill and expertness required in its performance. There are few patterns of the class that are regularly made for machine castings that require greater skill and expertness to complete than a bevel-wheel pattern.

As to the best method of working the teeth and attaching them to the rim of a gear-wheel pattern there has been much discussion amongst pattern-makers. Fig. 171 shows five methods of securing the teeth to the rim; each of these has its advocates. A gear-wheel pattern to be made properly should be made accurately; it matters not how well made otherwise, if not accurate it is not suited for the purpose for which gear-wheels are intended. Of the different methods shown here the author is decidedly in favor of securing the teeth as shown by No. 5. This method of securing the teeth to

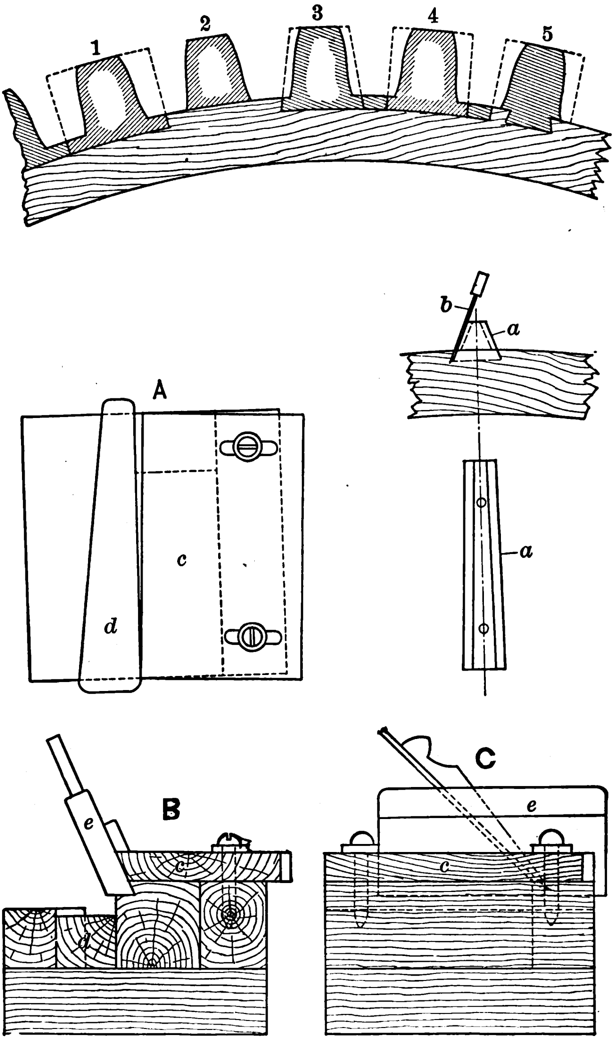


FIG. 171.

the rim is amongst the earliest practiced, and for accuracy and durability has no superior. The objection urged against this method that it is difficult to form suitable fillets at the roots of the teeth, owing to the delicacy of the edges there, is of small moment, because with care and the aid of sandpaper and shellac satisfactory fillets can be secured. The devices shown in connection with the teeth and rim of the wheel are intended to facilitate the working and attaching the teeth to the rim when method No. 5 is adopted. *A*, *B*, *C*, are respectively a plan, an end, and a side view of a combined box clamp and gauge by means of which the size and shape of the dovetail tenons on the tooth-blocks are worked. The gauge, *a*, is intended for use when cutting the dovetail slots in the rim; it is made of hard wood and equal in length to the face of the rim, and has a center line scribed through its length and on the ends. The angle of the sides should be about 22° 30′ with the center line, and the taper in length ⅜ inch per foot. The gauge in use is secured to the rim by two sharp-pointed wire brads, which are allowed to project to enable them to be readily withdrawn to change the position of the gauge. After the rim has been stepped off and lined, the gauge is secured to the rim by the pointed brads to coincide with a center line for a tooth. The saw, *b*, is applied and kept close to the side of the gauge while sawing the rim to the line scribed on the rim for the depth of the slot. After the sides of the slot have been sawed and the gauge removed, it is advisable to saw one or two kerfs between those outside. These will facilitate the removal of the material in working out the slot. The box, *ABC*, should be made substantial and of a size to allow its use for different sizes of teeth. The small sizes of teeth can be worked in the box by fitting a liner under the block and making a wedge, *d*, to suit the space between the block and the side of the box. The bottom of the box should be of sufficient thickness to allow the box to be held in the bench-vise while the dovetails on the blocks are being worked. The top of the box, *c*, which is the gauge for the taper and bevel for the dovetail tenon, is adjustable. The plane, *e*, is a rabbet beveled on the face to suit that of the gauge, *a*. A strip is secured to the side of the plane which, by bearing on the top of the box, *c*, gauges the depth of the dovetail. After one side of the dovetail tenons have been worked on the blocks the top, *c*, is reversed in angle and the remaining sides worked. The dovetail tenons should be made a trifle full for the slots, as a little fitting will be found necessary even when pains have been taken to insure accuracy, and for this reason, also, they should be somewhat longer than the width of the rim; they can be cut to the required length after being fitted into the rim.

If the teeth are to be cut by machinery, the blocks are secured to the rim by applying glue to about one-half inch at the large end of the dovetail. Gluing at one end only is to allow for any possible shrinkage of the rim. If the teeth are to be worked out by hand, the blocks, after the shape of the teeth have been laid off, are backed out, each being marked as it is removed from the rim; they are then worked in the usual way by being held by a hand-screw in the bench-vise while being shaped. In finally replacing the teeth in the rim three or four should not be glued; these should be properly marked: they are for the purpose of allowing the moulder to back them out to mend the mould should that become necessary.

As to the best material for making gear-wheel patterns there is nothing better than clear, soft, white pine for the body of the wheel and straight-grained cherry for the teeth. All of the material of course should be thoroughly seasoned and dry when used.

XXIII.

BELT-PULLEYS AND FLY-WHEELS.

IN Fig. 172, 1 represents a fly-wheel; 2, a belt-pulley; and 3, a gear-wheel design. Pattern-makers are frequently required to make patterns of wheels and pulleys without the aid of a prepared drawing. In such cases they will necessarily do their own designing and determine the proportion of the several parts. The following rules and formulæ will enable those unaccustomed to such matters to determine the various dimensions for wheels and pulleys within eight feet diameter:

a = width of face;
b = thickness of rim;
$c = \sqrt{a \times b}$;
d = diameter of wheel or pulley;
e = " " shaft
f = " " hub $= 1''.8 \times e$, for single pulley and $e \times 1''.9$ for double belt-pulley;
g = length of hub;
$h = .05 \times k + x$ = width of arm at hub;
$i = \frac{h}{2}$ = thickness of arm at hub;
k = length of arm;

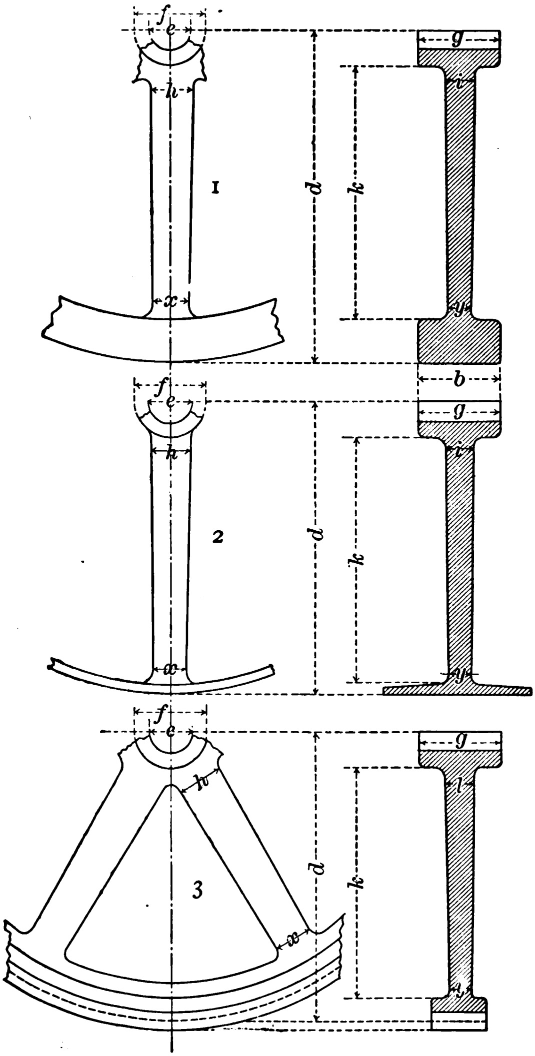


FIG. 172.

x = width of arm at rim;

$y = \frac{x}{2}$ = thickness of arm at rim.

The thickness of the edge of rims should be ″.25 for double- and ″.2 for single-belt pulleys, the thickness to increase ″.125 per foot to center of rim. The arms should be oval in section, the radius of the edges made about one eighth of the width of the arm. The application of formulas is apt to cause timidity in some mechanics when solving problems, but by following the examples worked out the dimensions of the details for any other diameter than that given may be easily arrived at by substituting the given diameter.

Example.

It is required to find the size of arms and hub for a single belt-pulley 48″ diameter for 3″ shaft.

Formula: $x = ''.375 + .04d$.

$x = ''.375 + 1.92 = 2''.3$ = width of arm at rim;

$y = \frac{x}{2} = \frac{2.3}{2}$ 1.15 = thickness of arm at rim;

$k = 24 - 3 = 21$ = length of arm.

$h = 21 \times .05 + 2.3$ = width of arm at hub;

$i = \frac{2.3}{2} = 1.15$ = thickness of arm at hub;

$f = 3 \times 1.8 = 5.4$ = diameter of hub.

A close approximation of the length of arm for pulleys can be obtained by subtracting the diameter of shaft from the radius of the pulley, as done in the above example.

Required the size of arms and hub for double-belt pulley 48 inches in diameter for 3-inch shaft.

Formula: $x = ''.85 + .04d$.

Example.

$.04d = 1.92$;

$x = .85 + 1.92 = 2''.8 =$ width of arm at rim;

$y = \frac{x}{2} = \frac{2.8}{2} = 1''.4 =$ thickness of arm at rim;

$k = 24 - 3 = 21'' =$ length of arm;

$h = 21 \times .05 + 2''.8 = 3''.85 =$ width of arm at hub;

$f = 3 \times 1.9 = 5''.7 =$ diameter of hub.

$i = \frac{3.85}{2} = 1.9 =$ thickness of arm at hub;

$g =$ length of hub, and will vary, according to diameter of pulley and width of face, from one and a half to three times the diameter of shaft.

For heavy rim wheels, such as fly-wheels, c, representing the volume of the rim, becomes a factor and $x = .85 + .04d + .153c$.

Required the size of arms and hub for fly-wheel 60 inches in diameter with a rim section (ab) of 4×6 inches, shaft 3.5 inches diameter.

Example.

$x = .85 + 2.4 + .75 = 4$ inches $=$ width of arm at rim;

$y = \frac{x}{2} = \frac{4}{2} = 2$ inches $=$ thickness of arm at rim;

$k = 30 - (3.5 + 6) = 20.5$ in. $=$ length of arm;

$h = 20.5 \times .05 + 4 = 5$ in. $=$ width of arm at hub;

$i = \frac{5}{2} = 2.5$ in. = thickness of arm at hub;

$f = 3.5 \times 2 = 7$ inches = diameter of hub.

For fly-wheels, also for pulleys when the pattern is likely to be used for other purposes than that for which it was specially designed, it is advisable to make the diameter of hub double that of the shaft. In so doing it adds but a small amount to the weight of the pulley, but it has the advantage of making the pattern available for a somewhat larger shaft, without alteration, if wanted for such.

In the case of fly-wheels like the foregoing example it will be found that the aggregate widths of the arms exceed the circumference of the hub, and when the arms are joined by a curve, a web will be formed around the exterior of the hub which greatly strengthens the latter. The proportions of fly-wheel rims will vary according to the fancy of designers, except in cases where a belt is to be used on the rim. Some will prefer to make the face the larger dimension, while others will make the side of the rim the larger dimension. In either case good proportions for rims are as 2 and 3.

When designing arms, etc., for gear-wheels the formula for double-belt pulleys can be used, with the addition of a web on the interior of the rim joining the arms at that part. The thickness of rim of a gear-wheel is usually made equal to that of the root of the tooth.

The number of arms a pulley should have will vary according to the diameter. Up to 10 inches, a solid web, or 4 arms; from 10 to 18 inches diameter, 5 arms; from 18 to 42 inches, 6 arms; and from 42 to 72 inches, 8 arms.

While it is advisable to abolish all sharp corners in castings, great care is necessary in applying fillets, as very large fillets, under some conditions, may become a source of weakness to a casting instead of adding strength. A casting is strongest when the metal is most uniformly distributed.

XXIV.

STANDARD PATTERNS.

STANDARD patterns when made of wood and which are often used should be made very durable. They should be made wholly or in part of hard wood, such as mahogany or cherry. Where dowel-pins are necessary they should be of metal. The metal dowel-pin should be about $1\frac{1}{2}''$ long and cylindrical for about $\frac{1}{8}''$ from the plate, then taper $\frac{3}{16}''$ to the point, which should be rounded. Made thus the plate can be set a little below the joint of the pattern and not interfere with the parts joining together properly. Wood dowel-pins answer their purpose very well for ordinary patterns and are cheaper than metal, but when a pattern with wood pins is often used the pins are liable to stick by becoming damp and swelling. When this occurs, very likely the moulder will enlarge the holes to such an extent that the doweled parts will not retain their proper position while being rammed up in the mould, and the result is a distorted casting. Rapping- and draw-plates are great pattern-savers and will well repay their cost when fitted to patterns that are used for many castings. There are several kinds of rapping- and draw-plates on the market very reasonable in price. Unless for a very large pattern, plates combining both rapping and draw features are the most convenient.

XXV.

GLUE AND ITS USE.

GLUE is indispensable in pattern work, but it is not every pattern-maker that can do a first-class job of gluing. The first essential for a good job of gluing is good glue. The author has always found the best Irish glue thoroughly reliable. With this glue in the hands of a competent workman who understands its use, there is no excuse for a bad gluing job. The glue should always be applied hot. Prepared liquid glues that can be applied without heating them are very convenient and will hold well for a while, but their adhesiveness seems to deteriorate with age and they are not so durable as glue applied hot. When large surfaces are to be glued the work should be warmed where possible. Pattern-shops are not usually provided with a special room that can be heated for gluing work. Where there is no special room for gluing up work it is advisable to heat the work previous to applying the glue. A good substitute is a steam-box. Such a box can be made of tongue-and-groove partition-stuff and need not be very expensive. A convenient size inside is about 16 ft. 6 in. long, 24 in. wide, and 24 in. deep. The cover should be hinged and in two parts as to length. A coil of 1-in. steam-pipe running along the bottom of this box should supply the heat. The box should be located convenient to the glue-heater.

XXVI.

LOOSE PIECES.

Loose pieces on patterns, although objectionable, cannot in many cases be avoided. They are often less objectionable than cores. When it becomes necessary to choose between a core and a loose piece the latter will generally prove the better because it will insure a truer casting. A core is especially liable to become misshapen by dressing and handling. Loose pieces are usually attached to patterns with draw-pins. Common brads with the end bent near the head make excellent draw-pins. In some cases it is advisable to fit loose pieces with dovetail tenons because when so fitted they are less liable to be misplaced while ramming up the mould. In fitting loose pieces with dovetails it is the practice with many pattern-makers to make the tenons parallel in thickness and have the taper on the two bevel edges only. This is objectionable, as they are liable to stick when so made. To insure the pattern being drawn easily and leaving the loose piece in the mould without distorting it, the dovetail tenons should be tapered both in width and thickness.

XXVII.

WOOD LAGGING FOR AN ELBOW.

In covering steam-pipes with materials of low heat-conducting properties for the purpose of retaining heat that would otherwise be dissipated, it is necessary, especially on vessels, to cover the non-conducting material itself, and thus increase its durability while giving it an appropriate finish. For this outside covering black-walnut lagging is largely employed. This work is usually done by pattern-makers.

In work of this kind peculiar shapes are frequently encountered which tax the skill and ingenuity of the workman in his effort to satisfactorily cover them. The most common are bends of pipes.

Figs. 173 and 174 show the different stages in constructing a right-angle bend for a pipe of wood lagging. On a suitable board, circles of the exterior and interior diameters of the bend are described, and from these the number of pieces or segments to compose the bend is determined. The cuts show a bend composed of twelve pieces, six in each half.

The material is first brought to the required thickness, according to the location of the several segments in the bend, as shown by 1, 2, 3, 4, 5, and 6, Fig. 173. These are all the pieces which compose one half the bend, 6 joining next to 1, 5 next to 2, and 4 next to 3. The different segments can be laid off directly on the material, but by the use of prepared templets the material can often be worked to better advantage.

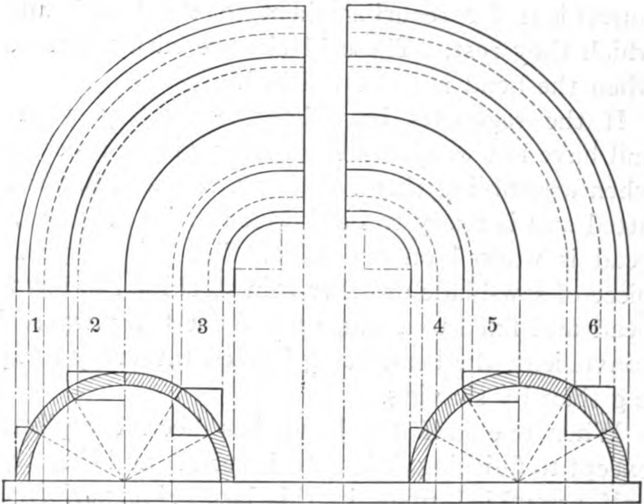
The figures show a plan and section of the different pieces and clearly illustrate the method of laying them off.

After the curvature of the pieces has been worked out, the next thing in order is to bevel the edges that the pieces may closely join when assembled. This bevel is required to be a radial line of the circles, Fig. 174. The thicker or outside segments are most conveniently beveled from the sides which are to be curved, and the thinner or inside pieces from the top or flat side.

The required thickness of the segments being gauged after beveling, they are worked to the exterior circle by templet. The insides are next worked out, which may be done roughly, as with these parts it is only necessary to approximate the circle.

When preparing to assemble the segments an outline of the bend is laid off on the board, and to this are secured semicircular blocks of the inside diameter at each end of the bend. As the segments are assembled, they are made to fit these blocks, which serve at once as guides and supports. Pieces

Fig. 173.



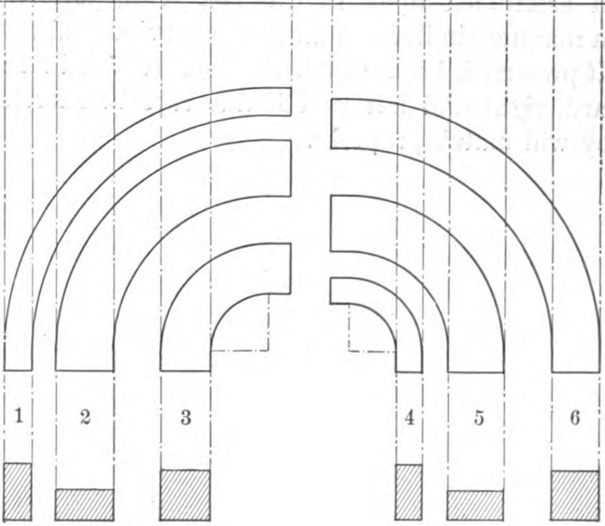


Fig. 174.

of pine block glued to the segments will be found convenient for securing them to the board upon which they rest. These blocks are easily removed when the bend is to be finished.

If the segments have been accurately worked and have not warped, little fitting will be necessary when assembling them. After a segment has been fitted and is ready to be doweled to its neighbor, a bead is worked on one edge. For this purpose a piece of saw-blade or other thin steel filed to form a bead and fixed to a gauge made for the purpose is convenient, the bead being formed rather by scraping than by shaving.

When one half the bend has been completed, except to finishing, it is to be inverted, and the other half assembled upon it, this last being performed in a manner similar to that of the previous half.

If preferred, both halves may be assembled on the board, right and left, and if due care be exercised they will match properly.

XXVIII.

THE LATHE AND LATHE-WORK.

THE first essential for doing good lathe-work is a good pattern-maker's lathe, which should be perfectly balanced and run steadily. When not specially designed for very small work it should be provided with a traveling carriage and slide-rest, also with outside or overhanging face-plate and floor-stand. The various appurtenances, such as chucks, face-plates, drivers, centers, etc., have much to do with a lathe's usefulness.

Some ingenious and handy fixtures for the lathe have been described. They are here reproduced, with some modifications and additions, in Figs. 175 and 176.

Referring to Fig. 175, *a* represents a driver which possesses some points of merit for large work.

With the ordinary spur driver with the spurs fixed and projecting nearly to the point of the center it is often difficult to readily swing the work between the centers. With this driver the chisel-points which do the driving are made adjustable by means of a collar with a screw-thread on its inner circumference. The driving points move in grooves

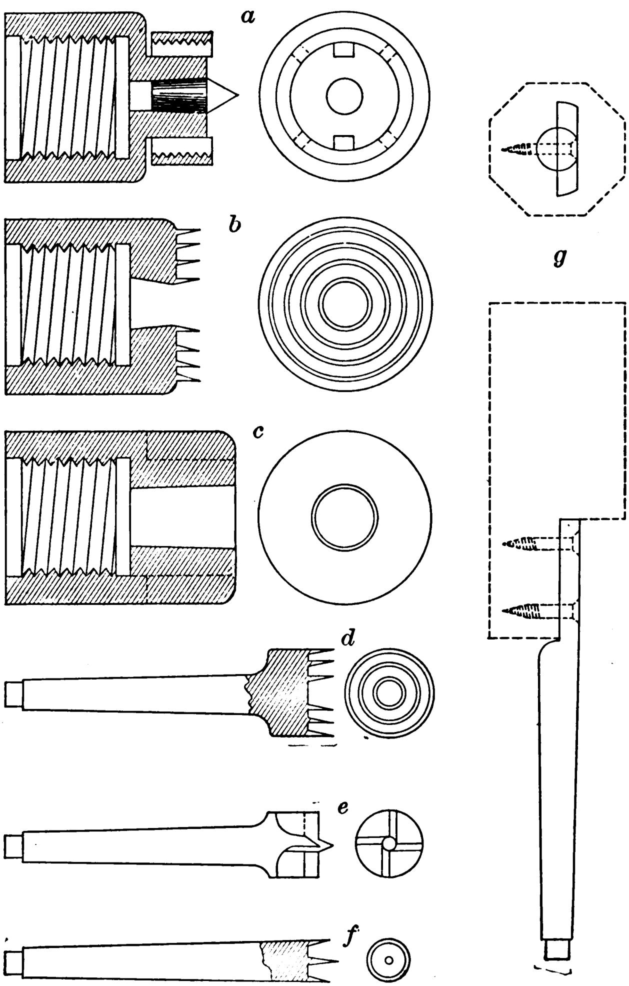


FIG. 175.

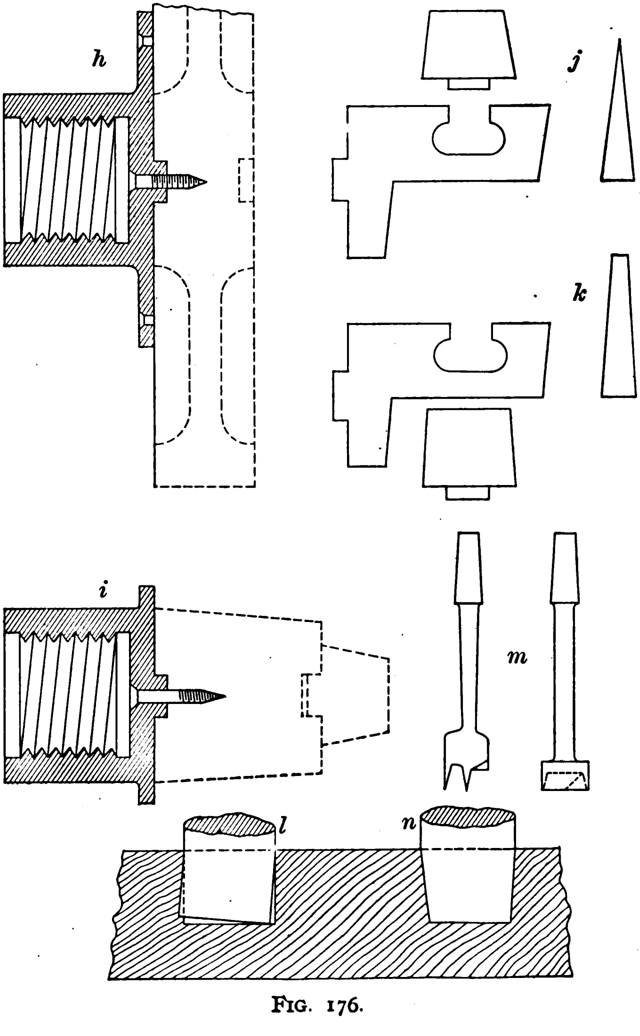


FIG. 176.

cut into the projecting end of the driver. These are threaded on their outer surface to match the collar. By this arrangement the driving points can be kept well out of the way until the work is swung between the centers. After the work has been swung the driving points can be moved out and forced into the work by revolving the collar and allowing it to bear against the end of the body of the screw-box. When the driving points are to be released the collar is revolved in the opposite direction. The points can then be withdrawn.

b shows another kind of driver, convenient where it becomes necessary to remove and again replace the work in the lathe. In such cases it insures the work being centered in the second instance exactly as it was in the first. The concentric rings on the driver should have the taper on their inner circumference and have their periphery parallel with the axis of the lathe. This will prevent any tendency, especially with parted work, to move outward.

c shows the ordinary socket-chuck to screw on the spindle. In some cases the hole for holding the work is wrongly made square. It should always be made circular and have a taper in the proportion of one inch per foot.

d shows a driver similar to *b* intended for smaller work and to fit the socket in the lathe-spindle.

e shows a good form of driver. It is made cylindrical and then milled away at the end so as to leave a central spur and four chisel-points for driving.

f shows a tail-stock center with a central spur and a concentric ring. In using this center it is good practice to fill this cavity with tallow or Albany grease before inserting it into the work, as it is difficult to oil when in the work. Every pattern-maker knows the difficulty even when the work has been centered in the first instance, of keeping it so in the lathe when using the ordinary single-spur centers. With the concentric-ring centers and drivers there is little liability of the work shifting after once being secured in the lathe, and should the work require removal from the lathe, it can be replaced exactly as it was before removal.

g shows a handy chuck where it is important to have the work accurately parted in the center. One side of the work is made longer than the other, and this long side is secured to the chuck by screws. The chuck's construction and application are so plainly shown as to make further explanation unnecessary.

In preparing jointed work for the lathe, especially that which is to swing between centers, and when sufficient time will permit, have the pieces of ample length and glue them together outside of the finished length. The glued part can be cut off after the work is removed from the lathe.

In Fig. 176, *h* shows a face-plate with a central boss finished to size and trued on the spindle of the lathe. The boss is to fit a hole bored into the work to be operated upon. A convenient size for the boss is one inch diameter and one-quarter inch long. The dotted lines serve to illustrate one of the most satisfactory operations of this simple fixture. The blank shown is finished on both sides. In operating on the first side a recess is turned in the center of the exact size to fit the boss on the face-plate. This insures the work being reversed and rechucked with accuracy. The recesses are also convenient for locating core-prints which are to be turned with a pin to fit the recess.

i shows a similar face-plate of smaller dimensions. The wood-screw shown in the center of the face-plate is preferable to the usual taper screw, because it is not so liable to split the work. The screw should fit the hole in the plate tight, but not so much so as to prevent its being backed out in case it is desired to use screws of different lengths.

For boring the recess to fit the center boss on the face-plate, a bit, *m*, should be prepared—a Forstner bit preferred. The bit should be kept handy to the lathe and not allowed to be used for any other purpose than that for which it is intended.

A great advantage will result from the adoption of a system for core-prints and have all core-prints conform to it. All core-prints for both drag and cope should be made tapered and core-boxes made so that the cores will fit the impressions made by the prints and not have cores larger than the prints, as is too often the case. In making core-boxes for cores which set vertically in the mould, it is the common practice to make the lower or drag print slightly tapered and the end of the core-box straight or cylindrical. Thus made there is always a liability of the core inclining, for the reason that the core when being set is apt to cut into one side of its seat as shown at *l*. When the print is given sufficient taper and the core-box made to suit it, there is less liability of the core not being properly set as shown at *n*. The pin on core-prints will be found advantageous when at any time it is desired to change the size of the core. A good standard for the taper of drag-prints is one-eighth inch in diameter for one inch in length; and for cope core-prints, one-quarter inch in diameter for one inch in length.

To facilitate the practice of this system of core-prints it is necessary to provide gauges similar to those shown at *k* for the drag, and at *j* for the cope core-prints. By means of these gauges the pins on the core-prints and the recesses for them in the pattern can be sized. Also the size and length of the prints gauged. A convenient place near the lathe should be provided for the gauges and bit, and care taken that they are always in their place when wanted for use.

XXIX.

HOW TO MAKE A WOODEN FACE-PLATE.

A COMMON way of making wooden face-plates for the lathe is to secure a plain wood plate to a cross. When using hand-screws with a plate made thus some of the screws are required to be set open to suit the thickness of the work and plate, and others to

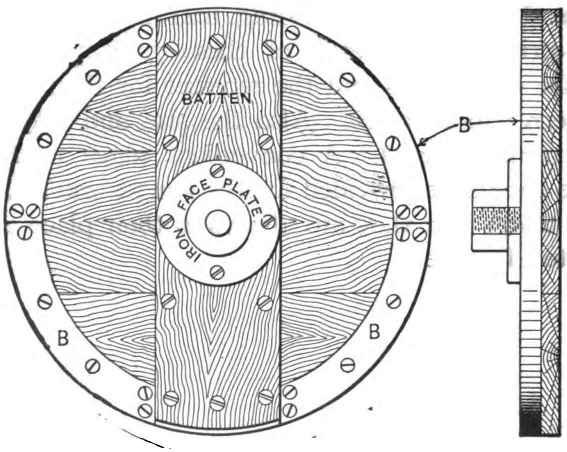


FIG. 177.

suit the thickness of the cross in addition. This condition often causes vexation by picking up the wrong screw in the hurry necessary when gluing up work. The annoyance thus occasioned may be avoided by securing segments of the thickness of the cross around the edge of the plate between the cross (see Fig. 177), then all hand-screws are required to be opened alike.

XXX.

MARKING, RECORDING, AND STORING PATTERNS.

It is now being recognized that patterns represent a large amount of money with some establishments, and economy requires that they should be properly cared for. Every concern using patterns to any extent should have a system of marking, recording, and storing them, and should not depend on the memory of persons for their identity and location. With a proper system any person of ordinary intelligence can be placed in charge of the pattern storage in case of the absence of the regular man whose business it is to take care of the patterns when the foundry has finished with them.

The nomenclature of machines and their various parts should originate and be decided upon in the draughtsmen's department, and this information should always be noted on the drawing. It is too often the case that the name of the machine or its parts is left to be decided upon in the pattern department. By the name, etc., being noted on the drawing there would in many cases be less difficulty in identifying a pattern.

Several systems are in use for marking and recording patterns, each having its merits and demerits. Some simply stencil or paint a number on the pattern and have a pattern accession-book in which the patterns are recorded. This system to be efficient needs to be combined with their proper care and storage, a feature too often neglected. This system has the disadvantage of the number, etc., becoming obliterated by continued use and neglect; but this objection can be overcome by renewing the stenciling when obscurity by wear becomes liable. With proper care stenciling will prove more durable than one would suppose who has had no experience with it.

Another method of marking is to stamp the number and name on the patterns with stencil-cutters. This indelibly marks it. The number of the pattern with whatever other necessary information in connection with it is recorded in a pattern-book.

It is desirable, especially when standard or particular lines of machines are manufactured, to have some mark to appear on the machine or its parts to enable them to be readily identified and to facilitate filling orders for such machines or their parts.

The system I would recommend, especially for establishments using a large quantity or a great variety of patterns, is:

1. Classify the patterns by placing in a class all similar machines. Where a machine is extensive and consists of many parts it may be given a class mark of its own. The different classes to be indicated by a letter or combination of letters.

2. Give each pattern a number. Where a pattern consists of a number of pieces, give each piece the same number as the main part of the pattern. Mark all core-boxes to correspond with class and number of their respective patterns.

3. Mark the pattern, its loose pieces, and core-boxes by stamping with stencil-cutters, and in addition secure raised letters and figures, for class and numbers, to the pattern so that they will appear on the casting. The advantage of stamping besides the lead figures, etc., is that if a figure becomes

Machine	*Chamber for 12" Stop Valve.*
Parts	*3 Pieces 4 C. Boxes.*
Castings	*1 right. 1 left. Cast Iron.*
Remarks. Made to change to right and left.	

FIG. 178.

lost from the pattern, the correct number will remain in the stamp and the loss will thereby be more readily discovered. In affixing the lead letters and figures to the pattern it is advisable to nail them and not depend on shellac alone to hold them.

4. Provide small printed forms, similar to the

sample shown in Fig. 178, to be filled in with pen and ink. The information on these forms, which can be about 2″×2″, should give the name and part of the machine the pattern is intended for, the number of pieces composing it, also the number of core-boxes belonging to the pattern, the number and kind of castings, and any other information deemed essential. These forms are to be fastened with shellac to a part of the pattern subject to the least wear, and when fixed are to be given two coats of shellac. Thus treated they will prove quite durable. The miscellaneous is likely to be the largest class of patterns. There are, however, many patterns of this class carried from year to year and never used that should be destroyed after being employed for the purpose for which they were made. The pattern storeroom should not be encumbered with a lot of patterns not likely to be used again for the purpose for which they were made.

For recording the patterns the card system possesses many advantages over recording in a book. The cards can be in duplicate or triplicate as deemed desirable for use in the drawing-room, pattern-shop, and pattern storeroom. All information about the pattern likely to be needed can be recorded on the card. Moreover, any change that becomes necessary can be readily noted on the card or a new card substituted. A desirable size for the recording cards is 3½″×5½″. A sample card is here shown (Fig. 179).

The pattern storeroom should be divided into sec-

Class	*A*
Number	*1492*
Drawings	*#1260*
Date	*Jan. 10-1901*
Corrections	*A.B.C.*
Machine	*12" Stop Valve*
Part of	*Chamber*
Pieces to	*3*
Pattern	
Coreboxes	*2*
Castings	*One Right. One Left*
Material	*Cast Iron*
Remarks.	
Drawing shows right-hand.	
Change Pieces stored with Pattern	

FIG. 179.

tions and marked to correspond with the class letters on the pattern.

When an order for castings from a pattern is completed in the foundry the man assigned to care for patterns should collect all pieces, core-boxes, etc., belonging to the pattern and clean them. Any repair needed should be done before the pattern is stored away. The pattern should then be stored in the section assigned to the class to which it belongs. When patterns are sent away to have castings made at a distant foundry the fact with any other necessary information can be noted on slips and filed with record-cards of the patterns in the card-rack—the slips to be removed from the card-rack when the patterns are returned.

XXXI.

SECTIONAL LINING IN MECHANICAL DRAWINGS.

WITH the general use of blue-prints in place of tracings, as formerly used for mechanical working drawings, it becomes necessary to adopt some particular marking when it is desired to designate the material to be employed. An effort is being made by the leading draughtsmen and technical journals to systematize the marking of mechanical drawings in this respect. Fig. 180 shows the markings most generally used at present.

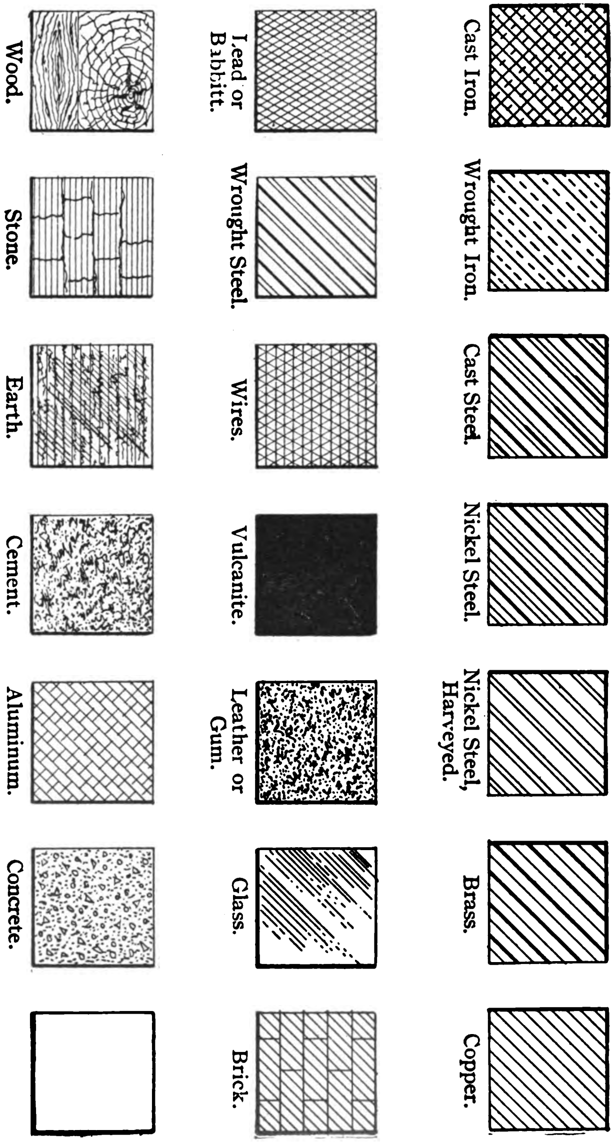

Cast Iron.
Wrought Iron.
Cast Steel.
Nickel Steel.
Nickel Steel, Harveyed.
Brass.
Copper.
Lead or Babbitt.
Wrought Steel.
Wires.
Vulcanite.
Leather or Gum.
Glass.
Brick.
Wood.
Stone.
Earth.
Cement.
Aluminum.
Concrete.

FIG. 180.

XXXII.

PRACTICAL GEOMETRY.

A KNOWLEDGE of even the rudiments of geometry is of great assistance to pattern-makers. The following geometrical problems, Figs. 181–192, are selected because of their more general practical application. If workmen will practice and familiarize themselves with their principles, they will add materially to a knowledge that will greatly benefit them in laying off work.

Fig. 181 illustrates the construction of a square on a given length of line. It also teaches how to erect a perpendicular on the line and at the end of it. Bisect the line *ab*, of given length; from the extremities *a* and *b* describe the intersecting arcs *c*; a line drawn from *c* to the bisection of *ab* will be perpendicular to the latter line. With one half the line *ab* as a radius, describe an arc from the point of bisection *o*, intersecting the perpendicular at *d*; a line drawn from *b* through *d* will produce a diagonal of the square. With the distance *db* as a radius, from the point *d* describe an arc intersecting *ab* and the diagonal at *c*; a line drawn from this last intersection to *a* will be perpendicular to the line *ab* and equal to its length, thus completing two sides of the square. With the distance *ab* or *ac* from the points *e* and *b* describe the intersecting arcs *f*. Lines drawn from this intersection to *b* and *e* will complete the square.

Fig. 182 shows how to describe an octagon in a given square. Construct the square as in Fig. 181. With one half of the diagonal as a radius, and from the points *a*, *b*, *e*, *f*, describe arcs intersecting the sides of the square, as *gh*, etc.; lines connecting these intersections will produce the octagon.

Fig. 183. To describe a hexagon in a circle. Draw center line and set off the diameter, *ab*. From *a* and *b* as centers, with distance *ao* and *bo* from *a* and *b*, cut the circle at *cm* and *en*. Connect these points with lines to complete the hexagon.

To describe a hexagon about a circle using Fig. 183. Draw center line of indefinite length and set *fg* for diameter. With radius *of* describe an arc of circle from *f* to *h* with the radius; connect *fh* with line. Draw *oh* and extend indefinitely. Draw a tangent to the circle parallel with the line *fh* and intersecting radii at *a* and *m*. From *o* as a center, with radius *oa* describe circle. From *a* and *b* as centers cut the circle with the radius and connect the intersections with lines as in the previous case.

Fig. 184. To describe a regular polygon of any required number of sides. From point *o*, with distance *ob*, describe semicircle *b* and *a*, which divide into as many parts, *a*, *c*, *d*, *e*, *f*, *b*, as the polygon has sides.

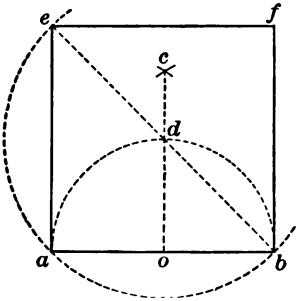


FIG. 181.

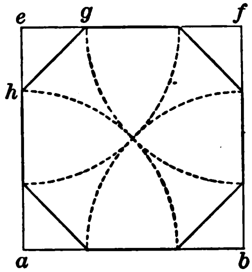


FIG. 182.

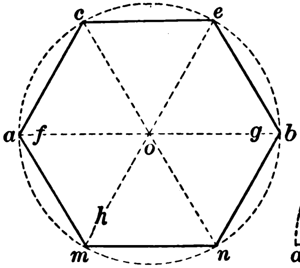


FIG. 183.

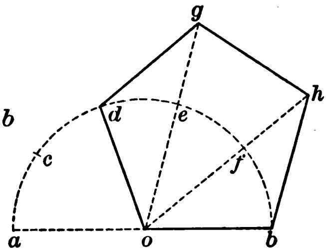


FIG. 184.

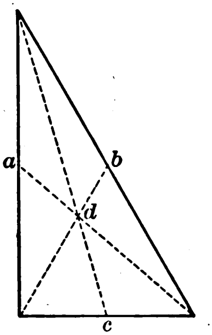


FIG. 185.

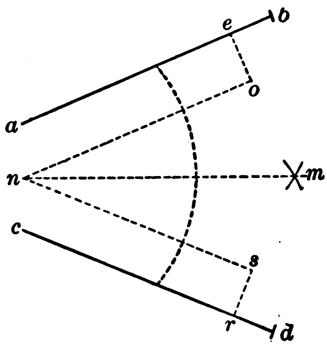


FIG. 186.

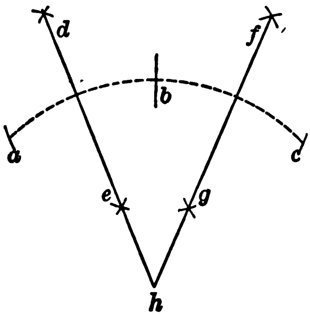


FIG. 187.

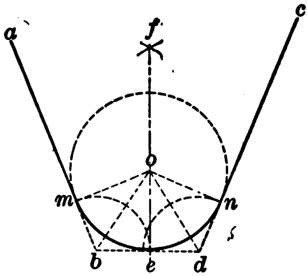


FIG. 188.

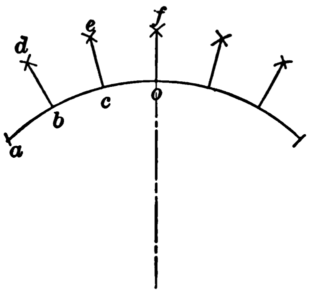


FIG. 189.

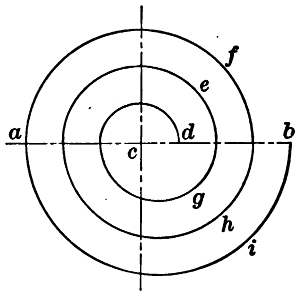


FIG. 190.

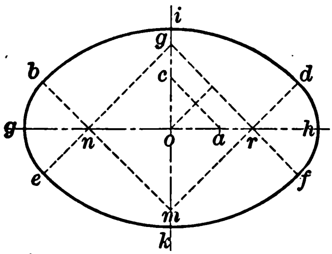


FIG. 191.

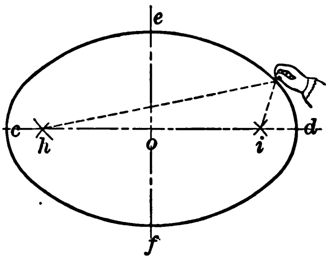


FIG. 192.

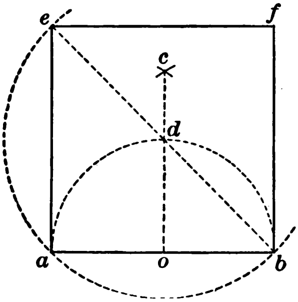


FIG. 181.

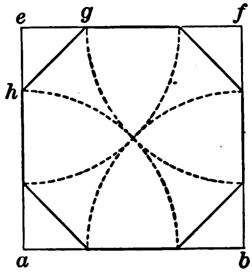


FIG. 182.

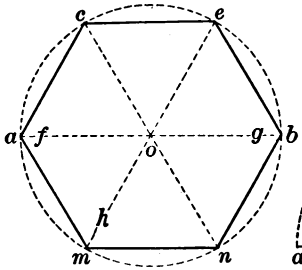


FIG. 183.

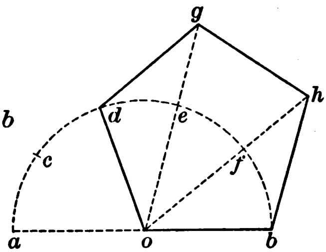


FIG. 184.

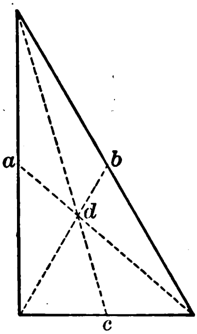


FIG. 185.

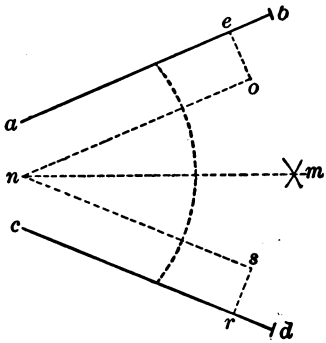


FIG. 186.

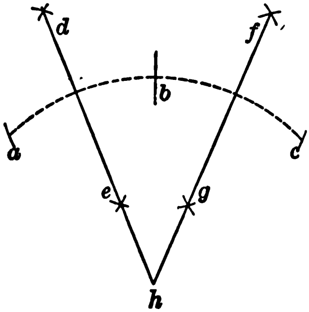


FIG. 187.

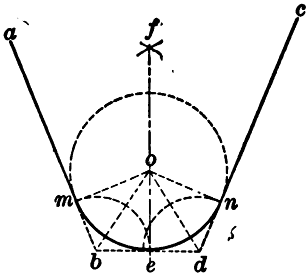


FIG. 188.

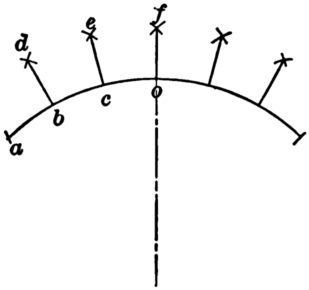


FIG. 189.

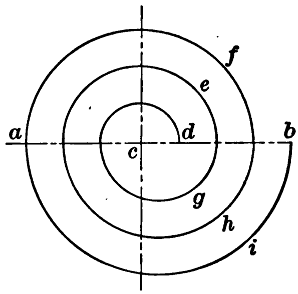


FIG. 190.

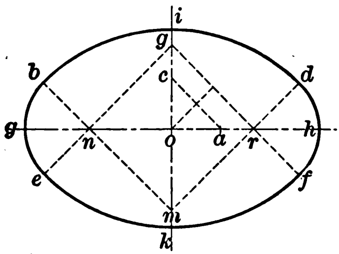


FIG. 191.

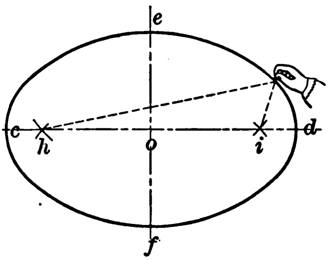


FIG. 192.

Thus let a pentagon be required. From *o* to the second point, *d*, draw *od*, and through the other points, *e* and *f*, draw lines extending indefinitely. Apply distance *ob* from *b* to *h* and from *d* to *g*. Connect these points. Or describe a circle intersecting *obd*, which will determine the points *g* and *h*.

Fig. 185. To find the center of a triangle. Bisect the sides of the triangle, as *a*, *b*, *c*. From *a*, *b*, and *c* draw lines to the angle opposite each, intersecting at *d*, the center.

Fig. 186. To bisect inclination of two lines when point of intersection is inaccessible. Upon given lines *ab* and *cd* at any point draw perpendiculars *eo* and *sr* of equal lengths, and from *o* and *s* draw parallels to their respective lines intersecting at *n*. Bisect the angle *ons*, and connect *mn* with a line which will bisect the lines as required.

Fig. 187. To find the center of radius of an arc. Divide the arc into equal parts, as *a*, *b*, *c*. From *a*, *b*, and *c* as centers, with a radius greater than their distance apart, describe intersecting arcs, as *de* and *fg*, both inside and outside of the arc. Draw lines through these intersections and extend them until they meet in the apex, as at *h*, which will be the center of the circle of which the arc is a part.

Fig. 188. To describe a circular segment which will fill the angle between two diverging lines. Bisect the lines *a*, *b*, *d*, *e* by lines *e*, *f*, and connect perpendiculars thereto to define the boundary of a segment to be described. Bisect angles at *b* and *d*

by lines intersecting at *o*, and from *o*, with radius *oe*, describe arc *men*.

Fig. 189. To draw from or to the circumference of a circle lines leading to an inaccessible center. Divide the whole or any portion of the circumference into the desired number of equal parts, as *a*, *b*, *c*, and *o*; then with any radius less than the distance of two divisions, describe intersecting arcs, as *d*, *e*, *f*. Draw lines from *d* to *b*, *e* to *c*, and *f* to *o*, and they will lead to the center.

Fig. 190. To draw a spiral about a given point. Assume *c* the center. Draw *ab* and divide into twice the number of parts that there are to be revolutions of line. From *c* describe the semicircles *d*, *e*, *f*; bisect the distance between *c* and *d* at *o*, and from *o* as a center describe semicircles *g*, *h*, *i*.

Fig. 191. To describe an ellipse, approximately, by circular arcs. Draw major axis *gh* and minor axis *ik*, set off their difference in length from *o* to *a*, and from *o* to *c* draw line *ac*; bisect its length and set off half from *a* to *r*; draw *rs* parallel to *ac*. Set off *on* equal to *or*, and *om* equal to *os*; from *s* and *m* draw lines through *n* and *r*, extending them indefinitely; from *n* and *r* as centers, with radius *rh*, draw the arcs *dhf* and *bge*; from *s* and *m* as centers, with radius *sf*, draw the arcs *ekf* and *bid*.

Note: This method is not satisfactory when the minor axis is less than two thirds of the major. An oval may be similarly described by circular arcs with any difference of major and minor axis.

Fig. 192. To describe an ellipse to any length and breadth. Draw the major axis *cd* and minor axis *ef*; from *c* and *d* as centers, with distance of half the major axis, describe arcs intersecting the major axis at *h* and *i*. Insert pins at *h* and *i*, and loop a string around them of such length that when a pencil is introduced within it will just reach to *e* or *f*. Bear upon the string and sweep around the center *o*, and an ellipse will be described. When an elliptograph is not available and the ellipse is to be constructed by points, the best and most accurate method of doing it is that shown by Fig. 193.

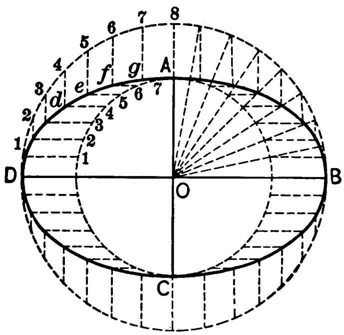


FIG. 193.

Let *DB* be the major and *AC* the minor axis, intersecting at right angles at the center *O*. With *O* as a center and *OC* as a radius describe a circle. From the same center, with *OD* as a radius, describe another circle. Divide the larger circle into any number of equal parts, and from these intersections draw radii which will also divide the inner circle correspondingly. From the points of intersection on the outer circle, as 1, 2, 3, etc., draw lines parallel with the minor axis, and from the intersections on the inner circle, as 1, 2, 3, etc., draw lines parallel with the major axis. The intersection of these lines, as at *a*, *b*, *c*, etc., will determine the curve of the ellipse.

XXXIII.

SOME USEFUL RULES FOR THE SHOP.

THE following problems are frequently met with in the workshops of various trades, especially in pattern-making. They are readily solved with the aid of a few figures, and the rules for doing so are easily applied, and require no higher knowledge of mathematics than that of arithmetic.

Probably the problem most frequently encountered is to find the radius of an arc of a circle that will intersect three given points. (See Fig. 194.) It can be found by the following rule: Divide the square of half the chord by the versed sine, or height, and to the quotient add the versed sine. This sum will then equal the diameter. Example: Let the chord of the arc equal 60 inches and the versed sine 10 inches; required the radius.

One half the chord	$60/2 = 30$ inches
The square of half the chord....	$30 \times 30 = 900$ inches
Square of half-chord divided by versed sine..............	$900/10 = 90$ inches
Diameter equals...............	$90 + 10 = 100$ inches
Radius equals................	$100/2 = 50$ inches

If it should be found inconvenient to describe the arc with trammels in consequence of the circle

FIG. 194

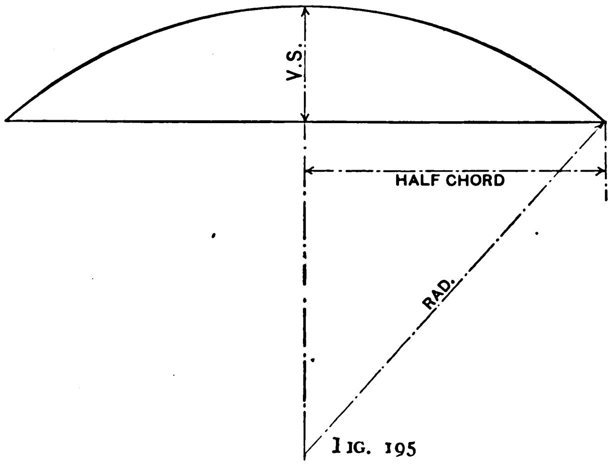
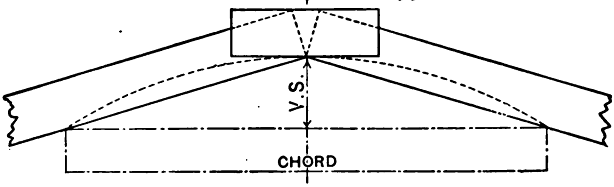


FIG. 195



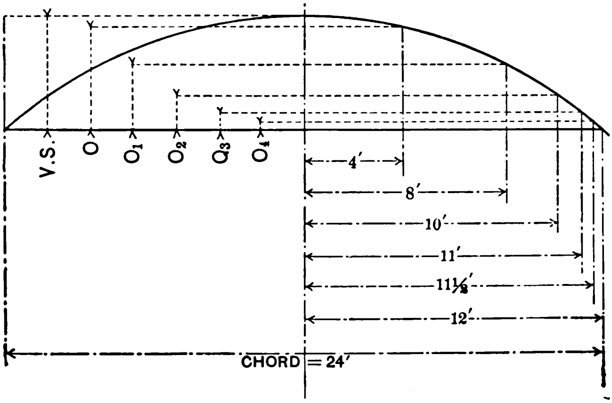


FIG. 196.

being very large or the center inaccessible, it may be described as follows, when the chord of the arc and versed sine are determined: Drive a wire brad at each extremity of the chord and also at the end of the versed sine. Then provide two straight-edges; the length of each must not be less than the length of the chord. Let the straight-edges bear against the brads at the ends of the chord, and one end of each bear against the brad at the end of the versed sine. In this position secure the straight edges together. Now withdraw the brad at the end of the versed sine and insert a scriber in the apex of the angle formed by the straight-edges. By moving the templet to the right and left while bearing against the brads at the ends of the chord, the desired arc will be described. (Fig. 195.)

When it is inconvenient to describe the arc by either of the foregoing methods, it may be arrived at by laying down the arc to a scale, erecting ordinates from the chord, and from the dimensions thus obtained develop to full size. The chord can be laid down full size, the ordinates erected from it, and with the aid of a batten intersecting their extremities the arc can be described. (Fig. 196.) But if greater accuracy is desired than is obtainable by this method, the arc may be determined by computing the length of the ordinates.

Let the diameter equal 304 feet.

Let the chord equal 24 feet.

In this case the first dimension to be found is the height of the versed sine, which is determined by the following rule: Subtract the square of half the chord from the square of the radius and extract the square root of the difference; subtract this root from the radius, and the remainder equals the versed sine. Example:

Radius equals. . . . . .304/2 = 152 feet
Half-chord equals. . . . . 24/2 = 12 feet
$152^2 - 12^2 = 23104 - 144 = 22960.$ $\sqrt{22960} = 151.5256$
Versed sine $= 152 - 151.5256 = .4744$ feet.

The versed sine being determined, the ordinates are found by the following rule: Locate the distance of the ordinates from the versed sine. Subtract the square of this distance from the square of the radius and extract the square root of the difference. Subtract the versed sine from the radius and then subtract this remainder from the root previously found, and the remainder is the required ordinate.

The difference of the versed sine and radius will be a constant in finding all of the ordinates.

As the distance from the versed sine is increased and the end of the chord is approached, accuracy is enhanced by diminishing the distance between the ordinates. Example:

$152^2 = 23104$
$4^2 = 16$

Diff. $= 23088$

$\sqrt{23088} = 151.9473$
$152 - .4744 = 151.5256$
$151.9473 - 151.5256 = .4217$ ordinate.

Similarly the other ordinates are determined.

$$\sqrt{152^2-8^2}-151.5256=.2637=o_1$$

$$\sqrt{152^2-10^2}-151.5256=.1451=o_2$$

$$\sqrt{152^2-11^2}-151.5256=.0758=o_3$$

$$\sqrt{152^2-11\tfrac{1}{2}^2}-151.5256=.0387=o_4$$

Another problem frequently met with in laying off work is to form an offset; that is, to join two parallel lines with a compound curve either by employing two different radii or a similar radius for both sides.

Having acquired the rule for computing the radius when the versed sine and chord of the arc are given, it becomes a simple matter for any one to compute the radii for this problem. In Fig. 197 it is required to have a uniform offset of three inches in a length of nine inches. The half-chord is one half of nine, or $4\frac{1}{2}$ inches, and the versed sine is one half the offset, or $1\frac{1}{2}$ inches. The center line of offset must be joined first, and from the centers thus determined the outside curves are described. By the rule given, Fig. 194, the diameter $=4.5^2/1.5+1.5=15$ inches. Radius equals $15/2=7\frac{1}{2}$ inches.

A peculiarity regarding this problem is that for like offsets the sum of the radii will always be equal, whether two similar or dissimilar radii are employed.. For instance, it is shown (Fig. 197) that for an offset of three inches in nine, with similar radii of curvature, the sum of the radii is 15

FIG. 197.

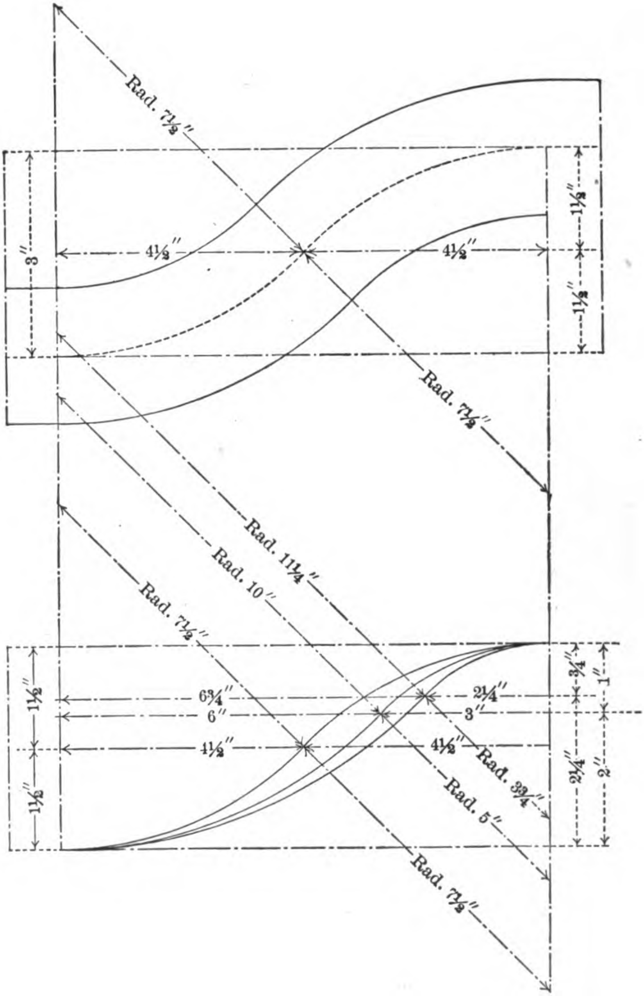


FIG. 198.

inches. If it should be desired to have one radius twice as great as the other, it is only necessary to take $\frac{2}{3}$ of 15, or 10, for one radius and $\frac{1}{3}$ of 15, or 5, for the other (Fig. 198). Or if it is desired to divide into $\frac{3}{4}$ and $\frac{1}{4}$, the radius will be respectively $11\frac{1}{4}$ and $3\frac{3}{4}$. This principle is graphically illustrated by Fig. 198.

There are many other such problems as the foregoing that are frequently met with in laying off work, and for the solution of which the cut-and-try method is employed, when by the use of a little arithmetic, with a knowledge of the principles involved, a solution could be obtained more readily.

Let it be required to cut a square out of a round stock, as in the case of a nut where a part of the length is cylindrical and a part square, the length of the side of the square only being given. To find the diameter to turn the cylinder, the majority of workmen would lay down the square and measure across the corners; but it can be computed more readily by the following rule: Multiply the length of side by 1.4142, and the product is the distance across the corners, or the diameter of the circumscribing circle. Example: The side of a square is 3 inches; required the diameter of the circumscribing circle.

$3 \times 1.4142 = 4.2426$ inches. (See Fig. 199.)

If, instead of a square, it is desired to find the circumscribing circle of a hexagon, use the following rule: Multiply the distance across the sides by 1.1547. Example: The distance across the sides of a hexagon is 3 inches; required the diameter of the circumscribing circle.

$3 \times 1.1547 = 3.4641$ inches. (Fig. 200.)

To find the circumscribing circle of an octagon, multiply the distance across the sides by 1.0824. Example: The distance across the sides of an octagon being 3 inches, required the diameter of the circumscribing circle.

$3 \times 1.0824 = 3.2472$ inches. (Fig. 201.)

A problem of common occurrence is to divide a given length into a number of equal parts, each part being separated by some object, as a rib or bracket. (Fig. 202.)

The usual way of working out this is to repeatedly try until the desired spacing is accomplished. I have found the following to be a convenient way of arriving at the proper spacing when the ribs are of uniform thickness. From the entire length subtract the thickness of one of the ribs and divide the remainder by the number of spaces, and the quotient will be equal to a space and a rib. With this distance begin at the inside edge of one of the ribs, as at *a*, and step off, terminating at the outside edge of the rib at the opposite end, as *b*. Then reverse this operation, beginning at *c* and terminating at *d*.

Example: A length of 90 inches, having five ribs 2 inches thick, is required to be divided into four parts and the ribs to be of equal distance apart.

$90 - 2 = 88$

$88/4 = 22 =$ the distance to step off with.

Of the various methods of constructing right angles without the aid of a square, the two following are the most convenient (Fig. 203). A triangle having its sides 3, 4, and 5 in length, or in this proportion, has one angle at right angles. Lay off AB equal to a

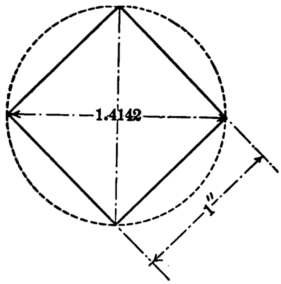


FIG. 199.

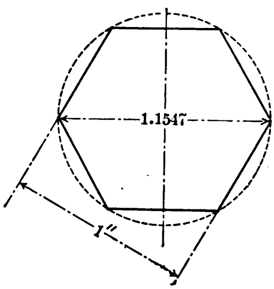


FIG. 200.

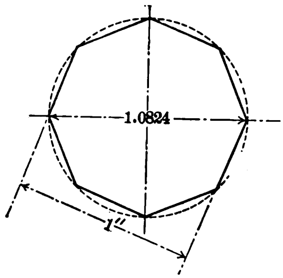
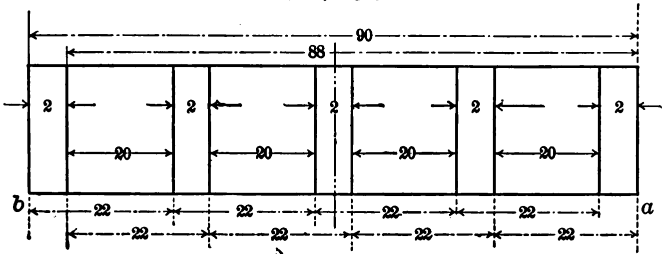


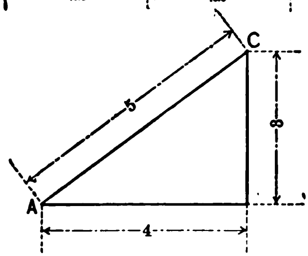
FIG. 201.

length of 4. With a length of 5 and with one point of the dividers at A describe an arc. With a length of 3 and with one point of the dividers at B describe another arc at C. Draw right lines from the intersections of the arcs to A and B. The triangle thus formed will have one right angle.

An angle circumscribed by a semicircle is a right angle (Fig. 204). Draw the line *AB*. Set a pair of dividers to any convenient distance and, with one point above the line, describe a semicircle intersecting the point *B* and the line between *A* and *B*; draw a line from this last intersection through the center intersecting the opposite side of the semi-

FIG. 202.





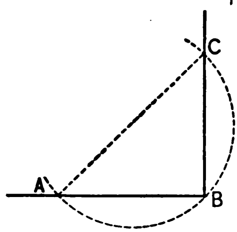


FIG. 203.

FIG. 204.

circle at *C*; draw a right line from *C* to *B*, and the angle thus formed will be a right angle.

To find the weight, length, or area of castings of the different metals in ordinary use.

Let A = area;

L = length;

W = weight;

C = weight of a cubic inch of metal.

$C = .0926$ for cast aluminum;
$C = .2482$ " " zinc;
$C = .2607$ " " iron;
$C = .284$ " " steel;
$C = .293$ " " brass;
$C = .3165$ " " bronze gun-metal;
$C = .3179$ " " copper;
$C = .4106$ " " lead;

Example: Required the weight of cast iron, 24 inches long, 2 inches in diameter; its length, and weight per cubic inch; its area.

$$A \times L \times C = W = 3.1416 \times 24 \times .2607 = 19.656, \text{ wt.}$$

$$\frac{W}{L \times C} = A = \frac{19.656}{24 \times .2607} = 3.1416 \text{ sq. inches, area.}$$

$$\frac{W}{A \times C} = L = \frac{19.656}{3.1416 \times .2607} = 24 \text{ in. long.}$$

$$\frac{W}{A \times L} = C = \frac{19.656}{3.1416 \times 24} = .2607, \text{ wt. cubic inch.}$$

To find the approximate weight of casting from weight of pattern.

The average weight of a cubic inch of the pine lumber used for patterns is about .015 pound. Then cast iron is $\frac{.2607}{.015}$ or 17.38 times heavier than the pine.

When a pattern does not contain cores, or where due allowance is made for cores and core-prints, an approximation of the weight of a casting may be arrived at by weighing the pattern and multiplying its weight by the following tabular number according to the metal required:

Cast aluminum	6.17
" zinc	16.5
" iron	17.38
" steel	18.9
" brass	19.33
" bronze, G. M.	21.1
" copper	21.2
" lead	27.37

XXXIV.

HANDY TOOLS FOR PATTERN-MAKERS.

FIGS. 205–208 show several handy devices for pattern-makers which, while they are not new, should be better known and more generally used.

Fig. 205 shows three views of the centering-plate, which is very convenient when describing a semicircle from a center situated on the edge of the work. It is made of brass about one-sixteenth inch thick. The semicircles *a* and *b* can be respectively about one and a half inches and one-half inch diameter, and should have their edges bevelled to allow the indicator marks to come close to the center line on the work. The apron, *c*, is about one-half inch wide and one-eighth thick. It projects perpendicularly from the under side of the plate and is the division between the two semicircles. The centers *d* and *e* for the divider-point are located over the edges of the apron. A line is scribed on the plate at right angles to the apron, passing through the two centers and extending to edges of the semicircles.

Fig. 206 represents the plate in use. A center line is scribed on the piece of work. The plate is held by one hand and adjusted to make the apron bear against the edge of the piece of work, and the indicator mark on the edge of the semicircle to match the center line on the work.

The large semicircle is applied for circles larger than its diameter, and the smaller for circles between the two diameters on the plate.

Fig. 207 shows a simple and excellent little tool for rounding the corners of patterns. *a* is a longitudinal section, *b* a view of the working face, and *c* a section on the line *de*. It is advisable to have about three of these tools, one for an eighth, one for a quarter, and one for three-eighths radius. The cutter, which is illustrated full size for quarter inch, is made of steel, about two and a half inches, and including the handle, about five inches long. Pattern-makers using these tools appreciate their value.

Fig. 208 shows a convenient device for obtaining the radii and laying off segments. *a* is a plan, and *b* a section. As illustrated it is intended for sixths of a circle, or a 60-degree angle. A brass plate having a small hole is fitted at the apex of an angle. The hole is intended for a center in setting the trammels, and is situated about one-tenth inch from the inside of the angle, to allow for fitting on the ends of the segments. Beginning at the center of the hole, one side of the triangle is graduated and marked in inches and fractions of an inch.

There should be several of these angles kept in a convenient place for the use of the shop. One should be for quarters, or 90 degrees. Two sizes

FIG. 205.

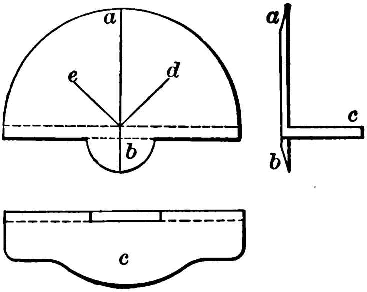
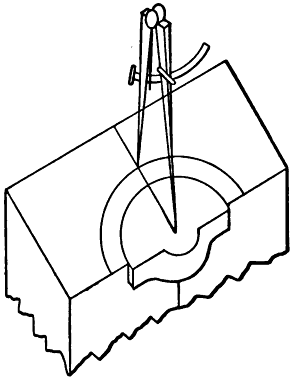


FIG. 206.



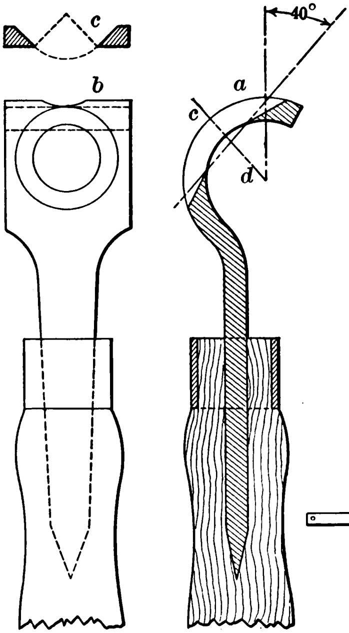


FIG. 207.

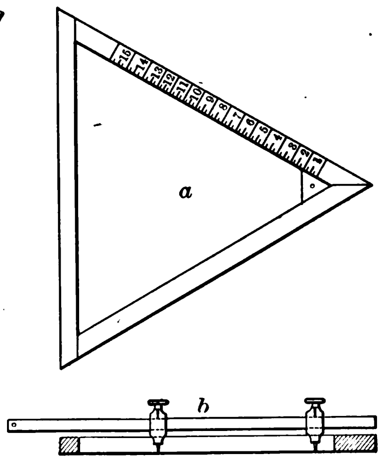


FIG. 208.

are necessary for sixths, or 60 degrees; one admitting of 15 inches and one of 30 inches radius. The one for eighths, or 45 degrees, should admit of a radius of at least 36 inches.

When preparing for a job of segment work it is the common practice to make a pattern to mark off the segments by. In using this segment gauge, as it may be called, the width of the piece intended for the pattern is immaterial if it is of sufficient size for the segment. It is simply necessary to secure the gauge to the piece of board, and the center of the circle will at the same time be located. The trammel can then be set by the graduations on the side of the triangle, the segment scribed, and its ends marked at the insides of the triangle.

XXXV.

METHOD OF MAKING SPECIAL SHRINKAGE RULES.

PATTERN-MAKERS sometimes require a special shrinkage rule that is not usually made or to be found for sale.

Figs. 209, 210 show a method of making such a rule by hand graduation, which when expertly done will give entire satisfaction.

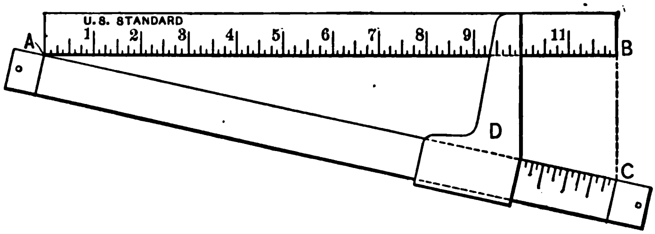


FIG. 209.

Secure a U. S. standard rule to a board so as to have the upper surface clear. Select a suitable piece of wood, preferably box, beech, or maple, make the piece perfectly straight, of the same thickness as the standard and somewhat longer than the required finished length.

Lay off from the end of the standard rule the additional length for the particular purpose required. With the radius AB, and one point of the trammel at A, describe an arc intersecting a line drawn at right angles from the end of the standard rule at C. Secure the blank to the board with its inner edge intersecting the points A and C. Make a gauge, D, of thin sheet steel with a guide flange turned down to bear against the outer edge of the blank.

The marking-tool should be thin and sharp and held in the same position during the graduation. A great deal depends upon this to secure accuracy.

XXXVI.

A HANDY STRAIGHT-EDGE FOR MARKING.

WHEN truing up a surface with a bench-plane it is the usual custom to use a straight-edge coated with chalk or some colored material, to mark the high places on the board. This substance is soon worn off by the repeated use of the straight-edge and consequently requires frequent renewal.

Fig. 210 shows a convenient device which obviates the use of chalk, etc., and is always ready for marking when wanted. A convenient size for this device is twenty-four inches long, three inches wide,

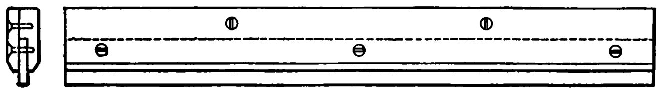


FIG. 210.

and the thickness made of two pieces of wood, one five eighths and the other three eighths of an inch thick. The thicker piece is rabbeted to receive a strip of sheet lead about two inches wide and one eighth of an inch thick, the lead being allowed to project outside of the wood about one-quarter inch. The two pieces are fastened together with screws to hold the lead firmly in place. The lead is easily kept straight by passing an iron plane over it occasionally.

XXXVII.

FILING HAND-SAWS.

THE hand-saw is one of the most important of pattern-makers' tools, as it is of all other workers in wood, and it is one of the most difficult of their tools to put in good order. Many excellent mechanics are not able properly to file a hand-saw without some device to aid them.

Fig. 211 shows an appliance that will not only be a help to the expert when filing saws, but will make it almost impossible for the novice to go wrong when intelligently applied. *A*, *B*, and *C* show a saw-clamp, which can be of any kind. It is provided with a shelf, *a*, extending from the back and at right angles with the blade of the saw. A piece of glass, *b*, preferably about a quarter of an inch thick, is secured to the shelf in such a manner as to be easily raised.

Three sheets of paper about the size of the glass are prepared with heavy lines so that the lines can be plainly seen when placed under the glass. One sheet has the lines at right angles to the saw-blade, to be used when filing rip- or band-saws. Two sheets have the lines at an angle, one extending to the right and one to the left, according to the bevel it is desired to have the teeth for cross-cutting.

D, the file, which is shown on a larger scale, is

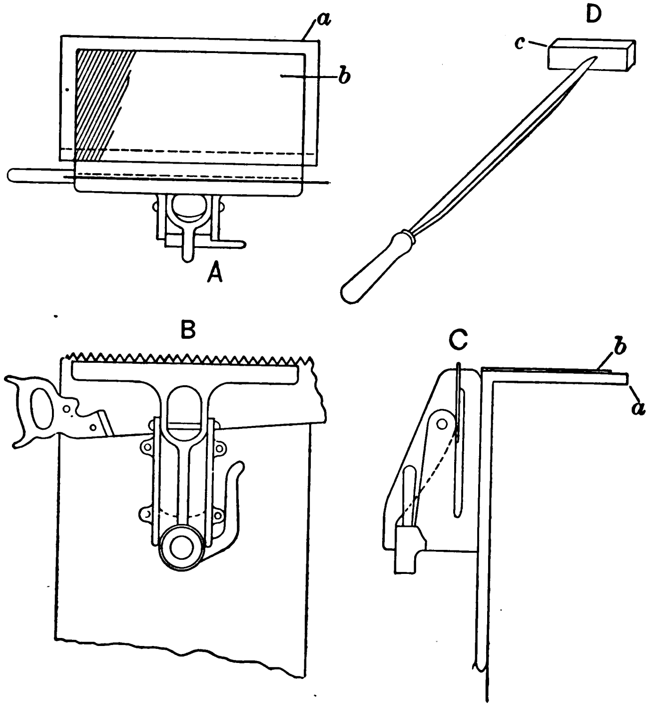


FIG. 211.

prepared by driving its point into a small block, *c*, about three by one by a half inch. The lower edge of the block is to rest on the glass and is slightly rounded. The position of the corner of the file to be used with reference to the curved edge of the block determines the rake of the teeth.

When prepared for use the sheet whose lines are required is exposed under the glass. The file with the curved edge of the block resting on the glass is to follow the lines when filing. Except when the teeth are very large it is well not to lift the block from the glass, but pass the file to the next tooth by raising the handle sufficiently.

XXXVIII.

WAX FILLETS.

Fig. 212 shows handy devices for making and applying wax fillets. *A* represents a press made of three-quarter-inch brass tube about five inches long; one end of the tube is securely closed by a wooden plug. A plunger made of close-grained hard wood is made to work in the tube; the fit should be as nearly air-tight as possible to make the plunger. A hole is made through the side of the tube close to the inner end of the plug. The diameter of the hole will be according to the size of the fillet desired; a diameter of one-sixteenth inch is suitable for quarter-inch fillets.

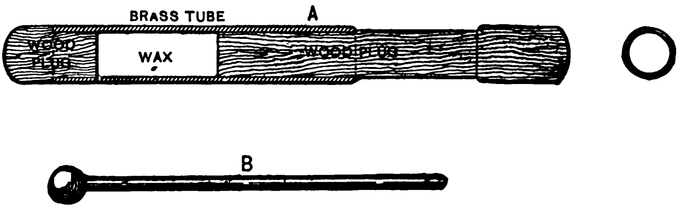


Fig. 212.

To make the fillet stock, beeswax is placed in the tube, and pressure applied on the end of the plunger, which will cause the wax to issue from the hole in an unbroken thread; this can be coiled and preserved for future use. The pressure can be applied by placing the ends of the press between the jaws of a hand-screw or bench-vise. *B* shows a tool, to be found on the market, made for forming wax fillets. The wax being placed in the desired corner, the tool, which has been heated in hot water, is applied and moved along the wax with sufficient pressure with the result that a neat and quick fillet is formed where a wood or leather fillet would be difficult. In the absence of the above tool, one can be improvised by grinding the end of a wire nail or a piece of wire to the required form.

XXXIX.

INSERTING WOOD-SCREWS INTO END GRAINS OF WOOD.

Wood-screws inserted into the end grains, especially of soft wood, do not take a very strong hold, but the hold may be increased by backing out the

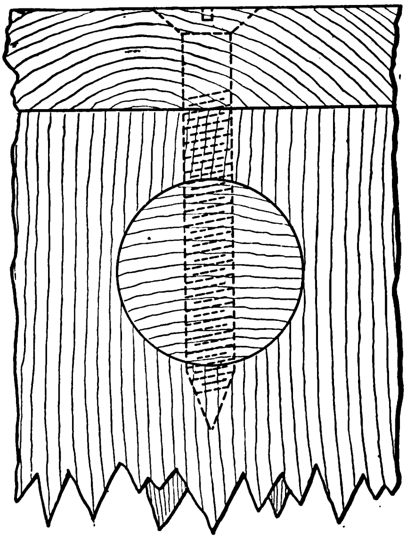


Fig. 213.

screw after being inserted and placing a small amount of glue in the hole and then reinserting the screw. When screws are to be taken out and reinserted into end-grain wood, as is often necessary where work is required to be taken apart in the foundry, simply screwing them into the end grain should not be depended upon, but a plug of hard wood should be inserted into the work and the screw allowed to pass through it at right angles to the grain of the plug (see Fig. 213). When the screw will no longer hold in consequence of its repeated withdrawals, the worn-out plug may be taken out and a new plug inserted.

XL.

BOARD MEASURE.

In board measure all boards are assumed to be one inch thick. When all dimensions are in feet—Rule: Multiply length by breadth, and product will give surface in square feet. Example: Required the feet, B. M., in a board 16 ft. long, 1.25 ft. wide, and one inch thick.

$$16 \times 1.25 = 20 \text{ feet.}$$

When either dimension is in feet—Rule: Multiply length by breadth, and the product by the thickness, and then divide by 12. Example: Required the feet, B. M., in a board 16 feet long, 15 inches wide, and $1\frac{1}{2}$ inches thick.

$$16 \times 15 \times 1.5 = 360, \text{ and } 360 \div 12 = 30 \text{ ft.}$$

When all dimensions are in inches proceed as before and divide by 144. Six inches and over are counted an additional foot.

XLI.

TO COMPUTE VOLUME OF SQUARED TIMBER.

WHEN all dimensions are in feet—Rule: Multiply length, breadth, and thickness together and product will give volume in cubic feet. Example: A piece of timber is 1.25 feet square and 20 feet long. Required its volume:

$$1.25 \times 1.25 \times 20' = 31.25 \text{ cubic feet.}$$

When either dimension is in feet proceed as before and divide by 144. Example:

$$\frac{15'' \times 15'' \times 20'}{144} = 31.25 \text{ cu. ft.}$$

When all dimensions are in inches proceed as before and divide by 1728. Example:

$$\frac{15'' \times 15'' \times 240''}{1728} = 31.25 \text{ cu. ft.}$$

Allowance is to be made for bark by deducting from each girth from .5 inch in logs with thin bark to 2 inches in logs with thick bark.

To reduce to board measure multiply cubic feet by 12, thus: $31.25 \times 12 = 375$ feet B. M.

Lineal feet is the length regardless of breadth and thickness.

XLII.

TIMBER MEASURE.

To compute the volume of round timber inside of bark. When all dimensions are in feet—Rule: Add together the squares of the greater and lesser ends, and the product of the two diameters. Multiply the sum by .7854 and that product by one third of the length.

Example: A piece of timber, barked, is 15 feet long. The diameters of the ends are 2 and 1.5 feet. Required the volume.

$2^2 + 1.5^2 + 2 \times 1.5 = 9.25$, which, multiplied by .7854, and that product by $\frac{15}{3} = 36.3247$ cubic feet.

When all dimensions are in inches proceed as before and divide by 1728.

To compute the square that a round log will cut. Rule: Divide the diameter of the small end inside of bark by 1.4142, and the quotient will equal the side of the square.

Example: A log is 14.5 inches in diameter at small end. Required the side when square.

$$\frac{14.5}{1.4142} = 10.253 \text{ inches.}$$

Or multiply diameter by 0.7071.

Thus $14.5 \times .7071 = 10.253$ inches, the length of the side of square.

XLIII.

STRENGTH AND WEIGHT OF WOODS.

THE strength and weight of the same kind of wood will vary considerably; this variation is caused by the conditions under which it grows, is prepared and seasoned. The following table, compiled from different authorities and the author's own experiments, exhibits a fair average for sound well-seasoned timber of the kinds given:

Kind of Wood.	Average Tensile Strength per Sq. Inch, in Lbs.	Average Crushing Strength per Sq. Inch, in Lbs.	Average Weight per Cubic Ft., in Lbs.
Ash, American	16,000	5,800	38
Beech	18,000	6,900	40
Cedar	10,300	6,000	35
Cherry	12,500	......	41
Chestnut	12,500	5,300	39
Cork	......	......	15
Cypress	6,000	......	27
Hickory	18,000	8,900	53
Mahogany, hard	20,000	8,800	53
" soft	8,000	......	35
Oak, American white	18,000	9,000	50
" English	19,000	10,000	55
" live, Ala	16,400	7,700	60
" upland	10,000	6,800	42
Pine, Southern Ga	10,000	8,900	45
" white	11,000	......	28
" white Mich.	......	......	26
" yellow long leaf	19,000	8,000	42
Poplar, yellow	7,000	......	31
Redwood, Pac. Coast	10,000	6,000	24
Spruce	11,000	6,800	29
Walnut, red	17,000	......	39
" black	......	......	37

XLIV.

MISCELLANEOUS TABLES, ETC.

TABLE OF DECIMAL EQUIVALENTS OF MILLIMETERS AND FRACTIONS OF MILLIMETERS.

1/100 mm. = .0003937″.

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
1/50=	.00079	26/50=	.02047	2=	.07874
2/50=	.00157	27/50=	.02126	3=	.11811
3/50=	.00236	28/50=	.02205	4=	.15748
4/50=	.00315	29/50=	.02283	5=	.19685
5/50=	.00394	30/50=	.02362	6=	.23622
6/50=	.00472	31/50=	.02441	7=	.27559
7/50=	.00551	32/50=	.02520	8=	.31496
8/50=	.00630	33/50=	.02598	9=	.35433
9/50=	.00709	34/50=	.02677	10=	.39370
10/50=	.00787	35/50=	.02756	11=	.43307
11/50=	.00866	36/50=	.02835	12=	.47244
12/50=	.00945	37/50=	.02913	13=	.51181
13/50=	.01024	38/50=	.02992	14=	.55118
14/50=	.01102	39/50=	.03071	15=	.59055
15/50=	.01181	40/50=	.03150	16=	.62992
16/50=	.01260	41/50=	.03228	17=	.66929
17/50=	.01339	42/50=	.03307	18=	.70866
18/50=	.01417	43/50=	.03386	19=	.74803
19/50=	.01496	44/50=	.03465	20=	.78740
20/50=	.01575	45/50=	.03543	21=	.82677
21/50=	.01654	46/50=	.03622	22=	.86614
22/50=	.01732	47/50=	.03701	23=	.90551
23/50=	.01811	48/50=	.03780	24=	.94488
24/50=	.01890	49/50=	.03858	25=	.98425
25/50=	.01969	1=	.03937	26=	1.02362

10 mm. = 1 centimeter = 0.3937 inches.
10 cm. = 1 decimeter = 3.937 "
10 dm. = 1 meter = 39.37 "
25.4 mm. = 1 English inch.

TABLE OF DECIMAL EQUIVALENTS OF 8THS, 16THS, 32DS, AND 64THS OF AN INCH.

8ths.	9/32= .28125	19/64= .296875
1/8= .125	11/32= .34375	21/64= .328125
1/4= .250	13/32= .40625	23/64= .359375
3/8= .375	15/32= .46875	25/64= .390625
1/2= .500	17/32= .53125	27/64= .421875
5/8= .625	19/32= .59375	29/64= .453125
3/4= .750	21/32= .65625	31/64= .484375
7/8= .875	23/32= .71875	33/64= .515625
16ths.	25/32= .78125	35/64= .546875
1/16= .0625	27/32= .84375	37/64= .578125
3/16= .1875	29/32= .90625	39/64= .609375
5/16= .3125	31/32= .96875	41/64= .640625
7/16= .4375	64ths.	43/64= .671875
9/16= .5625	1/64= .015625	45/64= .703125
11/16= .6875	3/64= .046875	47/64= .734375
13/16= .8125	5/64= .078125	49/64= .765625
15/16= .9375	7/64= .109375	51/64= .796875
32ds.	9/64= .140625	53/64= .828125
1/32= .03125	11/64= .171875	55/64= .859375
3/32= .09375	13/64= .203125	57/64= .890625
5/32= .15625	15/64= .234375	59/64= .921875
7/32= .21875	17/64= .265625	61/64= .953125
		63/64= .984375

TRIGONOMETRICAL EXPRESSIONS.

The diagram shows the different trigonometrical expressions in terms of the angle *A*.

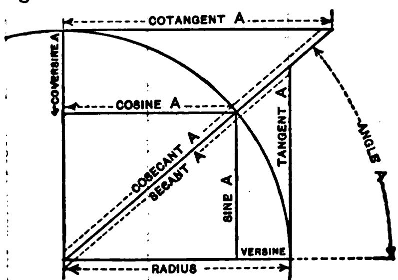


FIG. 214.

Complement of an angle = its difference from 90°.
Supplement . . . . = its difference from 180°.

MENSURATION OF SURFACES.

Area of circle	= Diameter²	× .7854
Area of ellipse	= Transv. axis × conjug. axis × .7854	
Area of sector of circle	= Arc	× ½ radius
Area of parabola	= Base	× ⅔ height
Surface of sphere	= Diameter²	× 3.1416

MENSURATION OF SOLIDS.

Cylinder	= Area of one end × length	
Sphere	= Diameter³	× .5236
Cone, or pyramid	= Area of base	× ⅓ height
Any prismoid	= Sum of areas of the two parallel surfaces + 4 times the area of a midway section × length, and the total product divided by 6.	

STEEL-WIRE FINISHING-NAILS SUITABLE FOR PATTERN WORK.

The gauge is that of the American Steel and Wire Co.

Size.	Length.	Gauge.	Approximate No. to Lb.	Diameter in Decim. of Inch.
	⅜ inch	No. 20	14240	.035
	½ "	" 20	8112	.035
	⅝ "	" 19	4848	.041
	¾ "	" 18	2928	.047
	⅞ "	" 18	2510	.047
2d	1 "	" 16½	1351	.058
3d	1¼ "	" 15½	807	.067
4d	1½ "	" 15	584	.072
5d	1¾ "	" 15	500	.072
6d	2 "	" 13½	309	.086
7d	2¼ "	" 13	238	.092
8d	2½ "	" 12½	189	.098
9d	2¾ "	" 12½	172	.098
10d	3 "	" 11½	121	.112
12d	3¼ "	" 11½	113	.112
16d	3½ "	" 11	90	.120
20d	4 "	" 10	62	.135

STEEL-WIRE COMMON NAILS.

Size.	Length.	Gauge.	Approx. No. to Lb.
2d	1 inch	No. 15	876
3d	1¼ "	" 14	568
4d	1½ "	" 12½	316
5d	1¾ "	" 12½	271
6d	2 "	" 11½	181
7d	2¼ "	" 11½	161
8d	2½ "	" 10¼	106
9d	2¾ "	" 10¼	96
10d	3 "	" 9	69
12d	3¼ "	" 9	63
16d	3½ "	" 8	49
20d	4 "	" 6	31
30d	4½ "	" 5	24
40d	5 "	" 4	18
50d	5½ "	" 3	14
60d	6 "	" 2	11

XLV.

STANDARD WOOD-SCREWS.

Wood-screws are very familiar and indispensable articles with pattern-makers, but it is doubtful if there is one in a hundred that could state the angle of the head if asked the question. The angle being 41 degrees, or the sides having a subtended angle of 82 degrees, accounts for the fact that the ordinary commercial countersinks which commonly have an included angle of 60 or 90 degrees are never just right for the heads of wood-screws.

Messrs. Asa S. Cook & Co., manufacturers of machinery for making wood-screws, have furnished the following table of data regarding the chief features of wood-screws as used by all of the principal makers of them in the United States.

U. S. STANDARD WOOD-SCREWS REDUCED TO THOUSANDTHS.

Body, also Flat and Round Heads.

Body.		Flat-head Dia. (Corner).		Round-head.	
No.	Diameter.	Sharp.	Round.	Diameter.	Depth.
0	.05784	.11	.10968	.106	.042
1	.071	.136	.1356	.130125	.051
2	.08416	.162	.16152	.15425	.06
3	.09732	.188	.18744	.178375	.069
4	.11048	.214	.21336	.2025	.078
5	.12364	.24	.23928	.226625	.087
6	.1368	.266	.2652	.25075	.096
7	.14996	.292	.29112	.274875	.105
8	.16312	.318	.31704	.299	.114
9	.17628	.344	.34296	.323125	.123
10	.18944	.37	.36888	.34725	.132
11	.2026	.396	.3948	.371375	.141
12	.21576	.422	.42072	.3955	.15
13	.22892	.448	.44664	.419625	.159
14	.24208	.474	.47256	.44375	.168
15	.25524	.5	.49848	.467875	.177
16	.2684	.526	.5244	.492	.186
17	.28156	.552	.55032	.516125	.195
18	.29472	.578	.57624	.54025	.204
19	.30788	.604	.60216	.564375	.213
20	.32104	.63	.62808	.5885	.222
21	.3342	.656	.654	.612625	.231
22	.34736	.682	.67992	.63675	.24
23	.36052	.708	.70584	.660875	.249
24	.37368	.734	.73176	.685	.258
25	.38684	.76	.75768	.709125	.267
26	.4	.786	.7836	.73325	.276
27	.41316	.812	.80952	.757375	.285
28	.42632	.838	.83544	.7815	.294
29	.43948	.864	.86136	.805625	.303
30	.45264	.89	.88728	.82975	.312
Ratio	.01316	.026	.02592	.024125	.009

Angle 41° }
Included angle 82° } Flat heads.

Length of thread is 7/10 of whole length of screw. Round heads, length measured from under head.

FORMULA FOR WOOD-SCREWS.

N = number; D = diameter.

$$D = (N \times .01325) + .056 \qquad N = \frac{(D - .056)}{.01325}.$$

XLVI.

HOW TO APPROXIMATE THE WEIGHT OF AN IRON CASTING FROM ITS OBSERVATION.

It occasionally happens that an approximate weight of a casting is desired where little or no opportunity is offered for measurements, and where simple observation of the pattern or casting is all that is available for data.

By remembering that a cubic foot of cast iron weighs 450 pounds, a square foot one inch thick 37.5 pounds, and 3.84 cubic inches weigh one pound, together with a little practice in judging dimensions, a fairly offhand, rough estimate can be made as follows: Judge the dimensions of pattern or casting and mentally estimate the cubical or superficial contents, then mentally multiply that by one of the above quantities accordingly as the case requires. For instance required the weight of a casting judged to be 10 by 5 feet and 2 inches thick. It will require very little mental exercise to determine that these dimensions will equal 100 square feet one inch thick, which, multiplied by 37.5, will equal 3750 pounds. By the same process of reasoning the weights for other metals can be determined by fixing in mind the necessary data for the metals. That for steel castings is 490 pounds per cubic foot, 40.86 pounds per square foot, and 3.522, or, roughly, 3.5 cubic inches per pound. But by far the most frequent occasion for this exercise will be for cast iron. The following tables are convenient for determining the length of bar of the different metals commonly used for weights.

TABLE I, GIVING WEIGHT PER INCH IN LENGTH OF ROUND BARS FROM 1″ TO 3″ DIAM.

Diam.	Cast Iron.	Cast Brass.	Cast Lead.	Cast Steel.
1 inch	.2042	.2301	.322	.2228
1⅛ "	.2584	.2912	.4075	.2821
1¼ "	.319	.3595	.503	.3482
1⅜ "	.3858	.4348	.6084	.4214
1½ "	.4594	.5179	.7244	.5015
1⅝ "	.5389	.6073	.8499	.5885
1¾ "	.6253	.7046	.986	.6526
1⅞ "	.7178	.8089	1.132	.7836
2 "	.8166	.9203	1.288	.8916
2⅛ "	.9219	1.0389	1.4538	1.0065
2¼ "	1.0337	1.1649	1.6301	1.1284
2⅜ "	1.1518	1.2979	1.8163	1.2573
2½ "	1.276	1.438	2.0122	1.3931
2⅝ "	1.4068	1.5854	2.2185	1.5359
2¾ "	1.5441	1.7401	2.435	1.6856
2⅞ "	1.6876	1.9018	2.6613	1.8423
3 "	1.8376	2.0709	2.8978	2.0061

TABLE II, GIVING WEIGHT PER INCH IN LENGTH OF SQUARE BARS, FROM 1" TO 3" SQUARE.

Side of Square.	Cast Iron.	Cast Brass.	Cast Lead.	Cast Steel.
1 inch	.26	.293	.41	.2838
1⅛ "	.329	.37	.519	.3591
1¼ "	.406	.457	.64	.4434
1⅜ "	.491	.554	.775	.5365
1½ "	.585	.659	.922	.6385
1⅝ "	.686	.773	1.082	.7494
1¾ "	.796	.897	1.255	.8691
1⅞ "	.914	1.03	1.441	.9977
2 "	1.04	1.172	1.64	1.1352
2⅛ "	1.174	1.323	1.851	1.2815
2¼ "	1.316	1.483	2.075	1.4367
2⅜ "	1.466	1.652	2.312	1.6008
2½ "	1.625	1.831	2.562	1.7737
2⅝ "	1.791	2.018	2.825	1.9555
2¾ "	1.966	2.215	3.100	2.1462
2⅞ "	2.149	2.491	3.389	2.3457
3 "	2.34	2.637	3.69	2.5542

Rule: Divide the given weight by the tabular number corresponding to the size of the bar and required metal.

Example: Required the length of a 20-lb. cast-iron weight of 1⅞" diameter: lbs. ÷ tab. number equals 20 ÷ .7178, equals 27.86 inches long.

Required the length of a 20-lb. cast lead weight of 1⅝" side of square. 20 ÷ 1.082 = 18.48 inches.

AREAS OF CIRCLES, AND LENGTHS OF THE SIDES OF SQUARES OF THE SAME AREA.

Diam. of Circle in Inches.	Area of Circle in Square Inches.	Sides of Sq. of Same Area in Sq. Ins.	Diam. of Circle in Inches.	Area of Circle in Square Inches.	Sides of Sq. of Same Area in Sq. Ins.
1	.785	.89	21½	363.05	19.05
1½	1.767	1.33	22	380.13	19.50
2	3.142	1.77	22½	397.61	19.94
2½	4.909	2.22	23	415.48	20.38
3	7.069	2.66	23½	433.74	20.83
3½	9.621	3.10	24	452.39	21.27
4	12.566	3.54	24½	471.44	21.71
4½	15.904	3.99	25	490.88	22.16
5	19.635	4.43	25½	510.71	22.60
5½	23.758	4.87	26	530.93	23.04
6	28.274	5.32	26½	551.55	23.49
6½	33.183	5.76	27	572.56	23.93
7	38.485	6.20	27½	593.96	24.37
7½	44.179	6.65	28	615.75	24.81
8	50.266	7.09	28½	637.94	25.26
8½	56.745	7.53	29	660.52	25.70
9	63.617	7.98	29½	683.49	26.14
9½	70.882	8.42	30	706.86	26.59
10	78.540	8.86	30½	730.62	27.03
10½	86.590	9.30	31	754.77	27.47
11	95.03	9.75	31½	779.31	27.92
11½	103.87	10.19	32	804.25	28.36
12	113.10	10.63	32½	829.58	28.80
12½	122.72	11.08	33	855.30	29.25
13	132.73	11.52	33½	881.41	29.69
13½	143.14	11.96	34	907.92	30.13
14	153.94	12.41	34½	934.82	30.57
14½	165.13	12.85	35	962.11	31.02
15	176.72	13.29	35½	989.80	31.46
15½	188.69	13.74	36	1017.88	31.90
16	201.06	14.18	36½	1046.35	32.35
16½	213.83	14.62	37	1075.21	32.79
17	226.98	15.07	37½	1104.47	33.23
17½	240.53	15.51	38	1134.12	33.68
18	254.47	15.95	38½	1164.16	34.12
18½	268.80	16.40	39	1194.59	34.56
19	283.53	16.84	39½	1225.42	35.01
19½	298.65	17.28	40	1256.64	35.45
20	314.16	17.72	40½	1288.25	35.89
20½	330.06	18.17	41	1320.26	36.34
21	346.36	18.61	41½	1352.66	36.78

AREAS OF CIRCLES, AND LENGTHS OF THE SIDES OF SQUARES OF THE SAME AREA.—*Continued.*

Diam. of Circle in Inches.	Area of Circle in Square Inches.	Sides of Sq. of Same Area in Sq. Ins.	Diam. of Circle in Inches.	Area of Circle in Square Inches.	Sides of Sq. of Same Area in Sq. Ins.
42	1385.45	37.22	51½	2083.08	45.64
42½	1418.63	37.66	52	2123.72	46.08
43	1452.20	38.11	52½	2164.76	46.53
43½	1486.17	38.55	53	2206.19	46.97
44	1520.53	38.99	53½	2248.01	47.41
44½	1555.29	39.44	54	2290.23	47.86
45	1590.43	39.88	54½	2332.83	48.30
45½	1625.97	40.32	55	2375.83	48.74
46	1661.91	40.77	55½	2419.23	49.19
46½	1698.23	41.21	56	2463.01	49.63
47	1734.95	41.65	56½	2507.19	50.07
47½	1772.06	42.10	57	2551.76	50.51
48	1809.56	42.58	57½	2596.73	50.96
48½	1847.46	42.98	58	2642.09	51.40
49	1885.75	43.43	58½	2687.84	51.84
49½	1924.43	43.87	59	2733.98	52.29
50	1963.50	44.31	59½	2780.51	52.73
50½	2002.97	44.75	60	2827.74	53.17
51	2042.83	45.20	60½	2874.76	53.62

XLVII.

PRISMOIDAL FORMULA.

(One Rule for the Contents of Various Bodies.)

A PRISMOID is a solid bounded by six plane surfaces, only two of which are parallel.

Every one who has had occasion to figure out the volume or contents of any regularly formed geometrical body has been perplexed in trying to remember the exact rule for each and the way to apply it. It is a happy state of the memory when every rule can be called to mind exactly when wanted. One rule is more easily remembered than a dozen. The following rule will solve all the problems of solidity for regular bodies:

Add together { The area of the base,
The area of the top,
Four times the area of the middle section.

Multiply this sum by one sixth of the perpendicular height. The resulting product is the cubical contents or volume required.

Applying the rule to a cone of 10 inches diameter of base and 12 inches perpendicular height:

The area of base	78.54
The area of top	00.00
Four times area of middle section	78.54
	157.08
Multiplied by one sixth of height	2
The volume in cubic inches equals	314.16

It will be observed of a cone that the middle section is a circle one half the diameter of the base, which is equal to one fourth its area; or, to state in another way, four times the area of a 5-inch circle is equal to the area of a 10-inch circle.

The rule applied to a cylinder of 10 inches diameter and 12 inches in height:

Area of base	78.54
" " top	78.54
Four middle areas	314.16
The sum of these equals	471.24
Multiplied by one sixth of height	2
The volume in cubic inches equals	942.48

This result agrees with the mathematical demonstration that a cylinder has three times the volume of a cone of the same height and diameter of base.

The rule applied to a cube of 12 inches:

The area of base	144
" " " top	144
Four middle areas	576
The sum equals	864
Multiplied by one sixth the height	2
Volume in cubic inches equals	1728

The rule applies equally to pyramids and prisms of whatever form of base or end. It also applies to frustums of pyramids, cones, and prisms.

Whether any of these bodies have their axes perpendicular to the base or not, this rule applies all the same, care being taken to use the perpendicular height, never the slant height.

To find the contents of a sphere 12 inches in diameter, use the rule the same way as for the cone, thus:

The area of base	00.00
" " " top	00.00
Four middle areas	452.39
The sum of these equals	452.39
Multiplied by one sixth of the height	2
Volume in cubic inches equals	904.78

There are some bodies formed like cigars, or that have what is called *spindle* shape, which require a little preparation before applying the rule for obtaining their contents. For such they must first be considered to be divided transversely at their largest part, and then calculate each part separately and add the results together for the sum.

In forms like these which have swelled sides there must be some means of counting in the swell, or convexity of these solids, and this very feature is included in the measures of this rule. The elements called "four times the area of middle section" brings in the swell and includes the difference between the volume of a cone of straight sides and having the same base and height, and of the spindle shape having convex sides. This element of the rule also covers the cases of cone-like figures having concave or hollow sides. Attention is particularly called to the necessity of taking in the exact measures of these and other similar forms, which every rule requires if the correct volume be sought for, because this result in every case can only be obtained from all the essential dimensions.

XLVIII.

TO COMPUTE THE AREA OF A FIGURE BOUNDED BY A CURVE.

THE following rule, known as Simpson's, is the one commonly used to compute the area of irregular figures:

Rule: Divide the line *ab* into any number of equal parts by perpendiculars from base, as 1, 2, 3, etc., which will give an odd number of points of division. Measure length of these perpendiculars and proceed as follows: To the lengths of the first and last ordinates add four times the lengths of all the even-numbered ordinates, and twice the sum of the odd; multiply their sum by one third of the distance between the ordinates, and the product will give the required area.

Required the area of a space 40 ft. long bounded on one side by a curve the ordinates of which are given in Fig. 215.

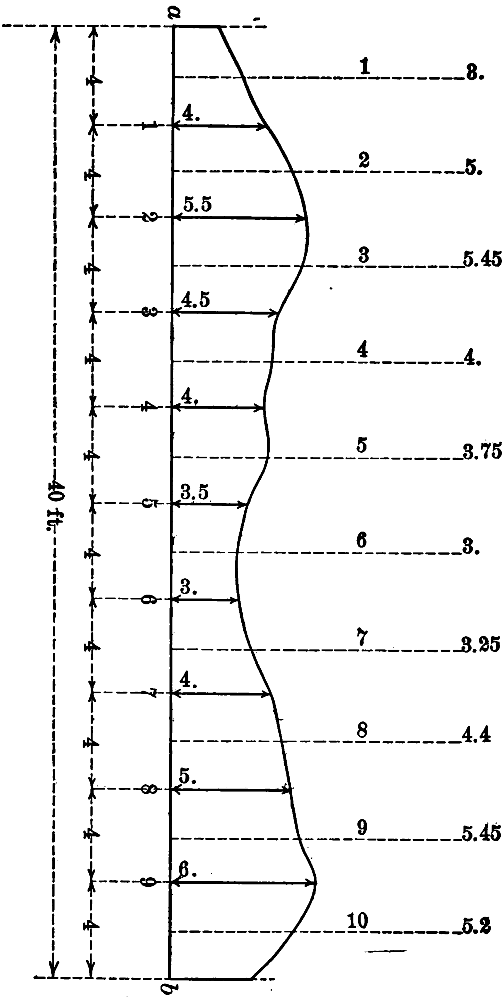


FIG. 215.

EXAMPLE.

Even.		Odd.		Sum.
No. Ord.	Length Ord.	No. Ord.	Length Ord.	
1	4.			
2	5.5	3	4.5	*a*. 2.
4	4.	5	3.5	*b*. 3.5
6	3.	7	4.	86.
8	5.	9	6.	36.
	$21.5 \times 4 = 86$		$18.0 \times 2 = 36$	$127.5 \times \frac{4}{3} = 170$ sq. ft.

The following is another rule which gives fairly accurate results, the accuracy depending in a great measure on the number of divisions and their mean lengths:

Divide the line *ab* into any number of equal parallel strips by perpendiculars from the base, as in the previous case; measure the mean lengths of the strips, as indicated by the dotted lines; multiply the sum of the mean lengths by the width of a strip, and the product will give the area.

EXAMPLE.

No. Ord.	Lengths Ord.
1	3.
2	5.
3	5.45
4	4.
5	3.75
6	3.
7	3.25
8	4.4
9	5.45
10	5.2
	$42.50 \times 4 = 170$ sq. ft.

XLIX.

WEIGHTS AND MEASURES.

AVOIRDUPOIS OR ORDINARY COMMERCIAL WEIGHT.

UNITED STATES AND BRITISH.

Ton.	Cwts.	Pounds.	Ounces.
1.	20.	2240.	35840.
0.050	1.	112.	1792.
	0.0089	1.	16.
		0.0625	1.

1 pound = 27.7 cubic inches of distilled water at its maximum density (39° Fahrenheit).

LONG MEASURE.

UNITED STATES AND BRITISH.

Miles.	Rods.	Yards.	Feet.	Inches.
1.	320.	1760.	5280.	63360.
0.003125	1.	5.5	16.5	198.
0.000568	0.1818	1.	3.	36.
0.0001894	0.0606	0.3333	1.	12.
0.0000158	0.005051	0.02778	0.08333	1.

The British measures are shorter than those of the U. S. by about 1 part in 17230, or 3.677 inches in a mile.

A fathom = 6 feet. A Gunter's surveying chain = 66 feet or 4 rods, 80 chains making a mile.

SQUARE OR LAND MEASURE.

UNITED STATES AND BRITISH.

Sq. Miles.	Acres.	Sq. Rods.	Sq. Yards.	Sq. Feet.	Sq. Inches.
1.	640.	102400.	3097600.	27878400.	
	1.	160.	4840.	43560.	6272640.
		1.	30.25	272.25	39204.
		0.0331	1.	9.0	1296.
			0.111	1.	144.
				0.00694	1.

CUBIC OR SOLID MEASURE.

UNITED STATES AND BRITISH.

1728 cubic inches = 1 cubic foot.

27 cubic feet = 1 cubic yard.

A cord of wood = 4′ × 4′ × 8′ = 128 cubic feet.

A perch of masonry = 16.5′ × 1.5′ × 1′ = 24.75 cubic feet, but is generally assumed at 25 cubic feet.

DRY MEASURE.

UNITED STATES ONLY.

Struck Bush.	Pecks.	Quarts.	Pints.	Gallons.	Cubic Inch.
1	4	32.	64	8.	2150.
	1	8.	16	2.	537.6
		1.	2	0.25	67.2
		0.5	1	0.125	33.6
		4.	8	1.	268.8

A gallon of liquid measure = 231 cubic inches.

A heaped bushel = 1¼ struck bushels. The cone in a heaped bushel must be not less than 6 inches high.

A barrel of U. S. hydraulic cement = 300 to 310 lbs., usually, and of genuine Portland cement = 425 lbs.

To reduce U. S. dry measures to British imperial of the same name, divide by 1.032.

NAUTICAL MEASURE.

A nautical or sea mile is the length of a minute of longitude of the earth at the equator at the level of the sea. It is assumed =6086.07 feet = 1.152664 statute or land miles by the United States Coast Survey.

3 nautical miles = 1 league.

USEFUL FORMULÆ IN MENSURATION.

1. Diam. × .8862 = Side of an equal square.
2. Circum. × .2821 = " " " " "
3. Diam. × .7071 = Side of an inscribed square.
4. Circum. × .2251 = " " " " "
5. Area × .6366 = " " " " "
6. Diam. × 1.3468 = Side of an equilateral triangle.
7. Circum. × .3183 = Diameter of circle.
8. Diam. × 3.1416 = Circumference of circle.
9. Side of square × 1.4142 = Diam. of circumscribing circle.
10. Side of square × 4.443 = Circum. of " "
11. Side of square × 1.128 = Diam. of circle equal in area.
12. Side of square × 3.545 = Circum. " " " " "
13. Square of diam. × .7854 = Area of circle.
14. Square of circum. × .07958 = " " "
15. Square of radius × 3.1416 = " " "
16. Half of circum. × half diameter = Area of circle.
17. Diam. × 0.7854 = Side of square of equal periphery as circle.
18. Side of square × 1.2732 = Diam. of circle of equal periphery as square.
19. Base × perpendicular height = Area of parallelogram.
20. Base × half perpendicular height = Area of triangle.
21. Half the sum of parallel sides × perpendicular height = Area of trapezoid.
22. Area of trapezium is found by dividing the figure into two triangles.
23. Long diam. × short diam. × 0.7854 = Area of ellipse.
24. Sum of sides × half perpendicular distance from center to sides = Area of any regular polygon.
25. Circum. × height plus area of the two ends = Surface of cylinder.
26. Diam. × 3.1416 = Surface of sphere.
    Circum. × diameter " " " "

27. Circum. or periphery × half slant height convex surface of cone or pyramid; for the entire surface add area of base to above product.

SOLID CONTENTS.

Prism, right or oblique, = Area of base × perpendicular height.

Cylinder, right or oblique, = Area of section at right angles to sides × length of side.

Sphere = Diameter cubed × 0.5236; also = Surface × 1/6 diameter.

Pyramid or cone, right or oblique, regular or irregular, = Area of base × 1/3 perpendicular height.

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