THE "PRACTICAL"
BOILER-MAKER, IRON SHIP-BUILDER,
AND
MAST MAKER.

By R. KNIGHT.

WYMAN'S TECHNICAL SERIES

THE "PRACTICAL"

BOILER-MAKER IRON-SHIP BUILDER AND MAST MAKER,

CONTAINING

MUCH USEFUL INFORMATION ON THE SUBJECTS NAMED;
ALSO, TEMPLATE MAKING IN GENERAL, AND IS
SPECIALLY VALUABLE TO ALL WORKMEN
IN THE IRON TRADE.

BY R. KNIGHT,
General Secretary of the Boiler-Makers' and Iron Shipbuilders' Society.

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PREFACE.

This volume is intended as a handbook for working-men, and to ensure its usefulness I have made the contents as simple as possible, to enable those who have not had the advantage of much education to master it with comparatively little trouble.

The beginning of any study is difficult; but when knowledge is obtained all studies become pleasant. A young man goes into a mechanic's shop as an apprentice. It is very difficult for him to acquire the skill demanded; but is it not worth his while to overcome the difficulty and acquire that skill? He has everything to learn, step by step, slowly, with many rebuffs and mortifications that require patience; but is not the ability that he gains worth all the pains he has bestowed in gaining it? If, therefore, a young man wants to become a good mechanic, he can only rise to that position by striving for it; he cannot secure it by the wave of his hand.

I am aware that the gradual development of capital, the absorption of small masters by large employers, a general breakdown of the apprentice system, the introduction of machinery, the sub-division of labour, and the constant hurry and drive of modern industrial employment, have all tended to make it most difficult for the young men of the present day engaged in skilled labour to acquire anything like a competent knowledge of their particular trades.

Sometimes a young man is shown how to do a job by "guesswork" or "rule of thumb;" but this only helps him for *that* particular piece of work. Should there be ever so little variation on another occasion, he is quite at sea, not having learnt the *principle* on which the job was executed. Again, if he sees a job properly set out and gone through in the workshop, and has no opportunity of speedily testing his recollection of the mode in which it was done, he forgets what he has learnt by the time the chance comes to him for putting it in practice. It is almost impossible, as a general rule, for a young beginner to apply any scientific knowledge he may have gained in the workshop. He would feel nervous at first in attempting it, and the chances are that the employer or foreman, seeing him pondering over it with a puzzled expression, would come up and ask him what he was about, saying "What are you wasting time for in trying experiments?" The workshop, therefore, is not the place in the present day where a young man can possibly learn a great deal connected with the trade which it is most important he should be thoroughly acquainted with.

The question arises, then, what is the remedy for this? One of the courses I would strongly recommend to all those who want to acquire a better knowledge than they already possess of their trade is the following: Get the best books that you can which treat with the subject, and carefully study the same in your quiet homes after the day's work is done. I know it is extremely difficult at first for a man to concentrate his attention upon any abstract subject after his daily labour, but let him try the following plan. Purchase a few sheets of card-board and a few drawing instruments (both may be obtained at an artist's shop for a small charge); then carefully strike out the diagrams contained in the book he has commenced to study. First, the drawings should be in the flat; then they should be cut out and *formed* into models. By such a method the student would see how to do the actual work as well as read about it, and the principle of the whole would be so impressed on the mind that it would not easily be forgotten.

I pursued studies according to this plan for many years, and found it of the greatest benefit; and from this practical experience it is strongly recommended. There are but few of the diagrams in this book the accuracy of which has not been tested by myself either in the workshop or at home. If you try this plan you will find it of immense help both to arouse your interest and to fix your mind on the subject under consideration. In fact, you would find it a pleasure to pursue your studies when you became more acquainted with the principles that underlie the correct method of marking out your work—to know, in fact, the "reason why" it has to be done in this or that way, and not in another. It will not only help to make you a workman worth more to your employer, but it will make you something more than a machine, enabling you to take both a pride and an intelligent interest in the work on which you are engaged.

In the production of this book, I do not claim the whole of its contents as being original; and I make this acknowledgment of my obligations to those whose works I have drawn from for information—namely, Sir W. Fairbairn's "Useful Information," E. and F. N. Spon's "Directory of Engineering," and Weale's "Modern Workshop Practice."

I have received valuable assistance from Mr. W. Fraser, of Sunderland, on "Mast and Yards."

A perusal of this book will, I think, convince the reader that by far the largest proportion of its contents are quite new, and have never appeared in any other work. Neither is it confined to one particular subject, but treats on "Boiler Making," "Iron Shipbuilding," "Mast and Yard," and Template making in general.

The large majority of problems contained in it are the product of study during my spare hours, extending over a period of many years. It is issued with the hope of making some contribution, however humble, to the true and permanent elevation of my fellow-workmen.

I trust the work in this form may promote their education, and that a direct and wide influence for good may be obtained.

R. KNIGHT.

APRIL, 1883.

SECTION I.

DIAMETER AND CIRCUMFERENCE OF A CIRCLE.

A circle is a plain figure bounded by one line, which is called the circumference.

The diameter of a circle is a straight line drawn through the centre and terminates both ways by the circumference.

The question may be asked—What is the ratio or proportion of the circumference to the diameter? At first sight this question seems quite absurd, for what ratio can possibly exist between two things that are perfectly unlike? The diameter of a circle is a straight line, but the circumference of a circle is a curved line. Therefore it does not appear that we can compare such two unlike things together; that is, they have no ratio to each other; and taking them as they actually exist in the circle, this is perfectly true. But if we say supposing that the circumference of a circle were stretched out in a straight line to its fullest extent, just as we should do with a wire ring by cutting it through in one part and then stretching it out in a straight line: What would then be the proportion of the circumference thus stretched out to the diameter of the circle? For instance, suppose that we take the crown of a hat and measuring it right across we find it to be 7 inches. Now take a string and measure it round, and it will be found to measure 22 inches; here then is the proportion in question as near as we require it, and will for all practical purposes apply to the making of rings, whether of round, square, or flat iron.

RULE.

As 7 is to 22 so is the diameter to the circumference, and in addition to this we must take into account the thickness of material, whether for an inside or outside diameter of ring.

Suppose we have two rings to make to fit, one inside and the other outside, of a given diameter.

EXAMPLE.

To make a ring 2 feet 9 inches in diameter, with iron ½-inch thick. Now for the outside ring we must add the thickness of the iron to the given diameter, which gives 2 feet 9½ inches for a new diameter. We now multiply the new diameter by 22 and divide by 7.

Thus 2 feet 9½ = 33½ inches—or thus,	33½
22	$3\frac{1}{7}$
67	100½
67	4½ $\frac{2}{7}$
7)737	$105\frac{2}{7}$ inches
$105\frac{2}{7}$ inches.	

Length required, 8 feet 9¼ inches.

For the inside ring we must subtract the thickness of the iron from the diameter, which gives 2 feet 8½ inches for a new diameter; to find the length of bar required we proceed as before.

Thus 2 feet 8½ = 32½ inches—or thus,	32½
22	$3\frac{1}{7}$
65	97½ $\frac{1}{7}$
65	4½
7)715	$102\frac{1}{7}$ inches.
$102\frac{1}{7}$ inches.	

Length, 8 feet 6⅛ inches.

If we require a ring made from a bar of iron ½-inch thick, and 3 inches broad, bent on the edge, we must then add the width instead of the thickness.

Weld or lap must be allowed.

I have given diameters, circumferences, and areas of circles on page 30.

ANGLE IRON RINGS.

Much has been written on the correct method of acertaining the length of a bar to make an angle iron ring of a given diameter, and if you were to examine all the books that profess to give information on the subject you would find that none of them agreed on the point, but each contained a rule quite different from the others. Many who have not had much experience in this class of work may be puzzled to account for this, as all of those books agree upon one *rule* for finding the length of a bar of either flat, round, or square iron to make a ring of any given diameter. The reason of this is no one *can* lay down any correct rule that would apply to all sizes of angle iron rings.

If you were requested to make a ring 2 feet in diameter flange outside, size of iron 3 × 3 × ½, and you found the length of the bar it would take to make it by *any rule*, which when bent it came to the exact size; and you also received instructions to make another ring, 6 feet diameter of the same iron, and you ascertained the length of bar to make by the *same rule* as you did the small one, you would find when this was bent that the bar in this case was too short to make the ring. This I am certain would be the case, although the *same rule* was adopted in both instances; and the reason of this is not far to seek. If you measured the outside flange of the small ring you would find that by bending the iron it had narrowed to about 2¾ inches, and if you were to measure the outside flange of the large one you would find it was nearly the same width as the bar was before it was bent; by this you will see at once that the iron in the large ring had not stretched to the same extent as the iron composing the small one, because it is nearer a straight line.

The mode of bending is also sure to alter the length. If care be taken in getting the bar to a uniform heat in the furnace, and then bend it around a block or pins to the diameter required, you will find that it will take a longer bar to make the same size ring than it would if you heated the bar at a smith's fire in lengths about a foot or eighteen inches at a time, as the iron stretches very much more by the last process.

The only correct method of finding the length of bar to make a ring of a given diameter is to strike out the full size of the ring on a piece of plate or a slab and draw a line across its centre; then to find the length of bar sufficient to make the ring, refer to table of circumference, or multiply the diameter by 22 and divide the result by 7. Example: supposing the diameter of the ring to be 3 feet, size of iron $3 \times 3 \times \frac{1}{2}$; reduce the diameter to inches and multiply thus—

$$\begin{array}{r l}
36 & \text{inches.} \\
22 & \\
\hline
72 & \\
72 & \\
\hline
7)792 & \\
\hline
113\frac{1}{7} & = 9 \text{ feet } 5\frac{1}{7} \text{ inches.}
\end{array}$$

To this add twice the width of the bar—namely, 6 inches, making a total of 9 feet $11\frac{1}{7}$ inches; take the bar and cut it that length, then mark it with a centre punch exactly in the middle; when this is done, scarfe the end of the bar and bend one-half of it according to the circle previously struck out, and by placing the scarfed end on the line that bisects the circle, you will see on the opposite side how near the centre punch-mark comes to the line; if it is one inch over the line towards the straight end of the bar it is a proof that the bar is two inches too long, and you must cut that amount off the straight end before bending the other half. If the centre punch mark does not come to the line by one inch, then you have cut the bar two inches too short; but this cannot be if the bar is cut according to the length before named.

If you want to make an angle iron ring with the flange inside, get the length of bar as before mentioned, but instead of adding twice the width of the bar, deduct once the width of the bar from the length and proceed as before.

It does not require as long a bar of iron to make a T iron ring as it does an angle iron ring, the diameter and thickness of iron being equal, as the former stretches much more than the latter. If you were going to make a T iron ring, 3 feet in diameter, refer to the table of circumference for the length and add twice the width of the rib to the length of the bar, and then mark it in the centre and bend one-half according to the previous instructions on the making of angle iron rings.

If you are going to make any quantity of either T iron or angle iron rings, do not cut up your iron and scarfe the ends until you have bent the half of one, as it will not take you much time in doing it, and you can then depend on getting the correct length, and in the end you will be very much the gainer in time and your employer in material.

The table of rules given you in many books for finding the lengths of iron to make either T iron or angle iron rings is only misleading, and is not in any case to be depended upon.

BOILER MAKING.

I am not going to give you a list of the different classes of boilers constructed, or enter into the different opinions expressed as to the best form of boiler adapted to supply the greatest quantity of steam with the least expenditure of fuel, or give you the dimensions or capacity of a class of boilers suitable for an engine of a given number of horse power. These are questions which you, as boiler-makers, have but very little to do with, the one that affects you most is the construction of boilers, and to this we will apply ourselves in such a manner easily to be understood.

Almost all high pressure boilers are now made circular in shape, and we will now suppose that we have one to make of the following dimensions—viz., 21 feet long, and 6 feet diameter inside, with a steam chest 3 feet high, and 2 feet 6 inches in diameter. The shell to be composed of inside and outside rings; thickness of iron $\frac{3}{4}$-inch. The outside measurement of the inner ring must be of the same diameter as the inside diameter of the outer ring. The inside ring being 6 feet in diameter, to this must be added the thickness of the iron—viz., $\frac{3}{4}$-inch, making 6 feet $0\frac{3}{4}$ inch; by referring to the table for that diameter, opposite which will be found, in the column of circumferences, 19 feet $0\frac{1}{2}$ inch, this is the exact length of plates, but as the rivet holes are to be 2-inch pitch, it will be seen at a glance that they will not work in exactly on account of the odd $\frac{1}{2}$-inch. We must therefore take the circumference at 19 feet. There is generally three plates used to compose the ring; the circumference named, divided by three, gives you 6 feet 4 inches for each plate in length, from centre to centre of rivet holes, to this must be added the lap at each end of the plate. To make good work we must allow lap equal to one-and-a-half the diameter of the rivet used; the lap will therefore be at each end of the plate $\frac{3}{4}$-inch, and half the diameter of the rivet holes—equal $\frac{3}{8}$; total lap, $1\frac{1}{8}$-inch: multiply this by $2 = 2\frac{1}{4}$ inches, add this to 6 feet 4 inches, makes the total length of each plate 6 feet $6\frac{1}{4}$ inches.

We now want to find the length of plates for the outside ring. On account of taking off $\frac{1}{2}$-inch in the length of the inner ring of plates to allow for the holes to be punched at a 2-inch pitch, we reduce the diameter about $\frac{1}{8}$ of an inch—namely, to 5 feet 11$\frac{7}{8}$ inches, to this must be added twice the thickness of the plate, being 1$\frac{1}{2}$ inch, thus the inside diameter of the outer ring will be 6 feet 1$\frac{3}{8}$ inch; this being the outside measurement of the inner ring when the plates are put together. To this diameter must be added $\frac{3}{4}$-inch the thickness of plate, making the new diameter 6 feet 2$\frac{1}{8}$ inches; by referring to the table of circumferences you will find the length to be 19 feet 4$\frac{1}{8}$ inches; divide this by 3, the number of plates composing the circle will give you 6 feet 5$\frac{3}{8}$ inches, being the length of outside plates from centre to centre of rivet holes; to this must be added 2$\frac{1}{4}$ inches for lap, making a total length of 6 feet 7$\frac{5}{8}$ inches.

In making your template for the outside plates you must carefully measure off your holes on the long edges, so as to get the same number in the outer plate as in the inside one.

We will now deal with the length of the boiler so as to ascertain the exact width the plates will be required.

The total length of the boiler is to be 21 feet inside. If we put an angle iron ring at each end 3 × 3 × $\frac{1}{2}$ inch, we should mark the holes in the rings 1$\frac{3}{4}$ inches from the root of the angle iron; then 1$\frac{3}{4}$ multiplied by 2=3$\frac{1}{2}$ inches, which has to be subtracted from the 21 feet, leaving a total length of 20 feet 8$\frac{1}{2}$ inches from centre of rivet holes, measuring from one end of the boiler to the other.

Now if we decide on making the boiler with seven rings of plates, we must divide the length by 7, which will give us 2 feet 11$\frac{1}{2}$ inches width of plates from centre of rivet holes, to this must be added the lap 2$\frac{1}{4}$ inches, making the total width of plate 3 feet 1$\frac{3}{4}$ inch.

The two templates for marking off the inner and outer rings of plates will be as follows:—Length of template for inside rings, from centre to centre of rivet holes, 6 feet 4 inches; lap, $2\frac{1}{4}$ inches; total length, 6 feet $6\frac{1}{4}$ inches.

Length of template for outer ring of plates, 6 feet $5\frac{3}{8}$ inches, from centre to centre of holes. To this must be added the lap, $2\frac{1}{4}$ inches; total length, 6 feet $7\frac{5}{8}$ inches.

The width of all the plates will be equal—namely, 2 feet $11\frac{1}{2}$ inches from centre of holes; lap, $2\frac{1}{4}$; total width, 3 feet $1\frac{3}{4}$ inch.

This boiler would be composed of four inside rings of plates, and three outside. The long edges of the template, for the inside ring of plates, must be marked off at a 2-inch pitch. The long edges of the outside template must contain exactly the same number of holes as the long edges of the inside template does.

The ends of both templates must contain an equal number of holes, carefully marked off with a pair of spring dividers, as near a 2-inch pitch as possible. In punching these plates care should be taken that the small sides of the holes come together when the plates are bent and placed in their respective positions. All that has to be done is to turn over each plate when both sides and one end are punched, and punch the remaining end on the reverse side.

We will now mark out the steam chest. It matters not whether it is to be in one or two plates, get the circumference required by the same means as is employed for casing templates.

There are two methods, the first is as follows:—Take your trammels and strike half a circle, the same diameter as your boiler; also mark off your steam chest on the top full size, as shown in figure 1. Also draw a horizontal line A touching the top of the large circle. Also draw a half-circle over the top of the steam chest and divide one quarter into any given number of equal parts with a pair of compasses, as shown at B. When this is done, draw parallel lines with the side of the steam chest from the circle down to the top of the boiler.

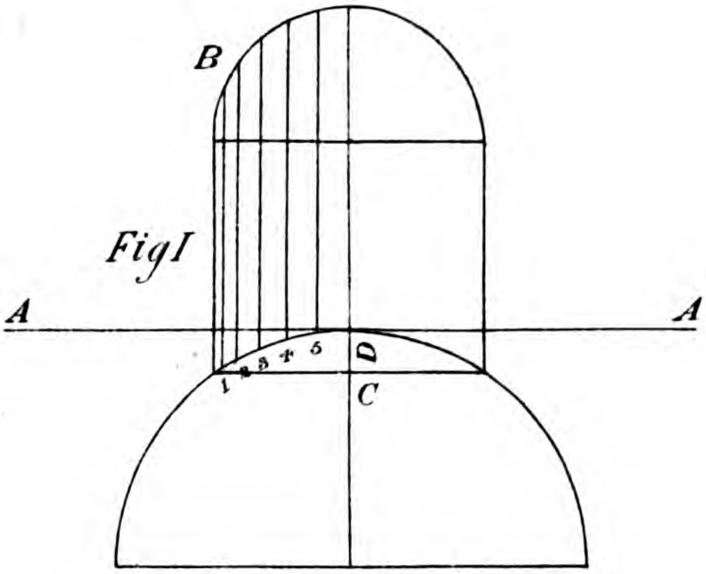


Fig I

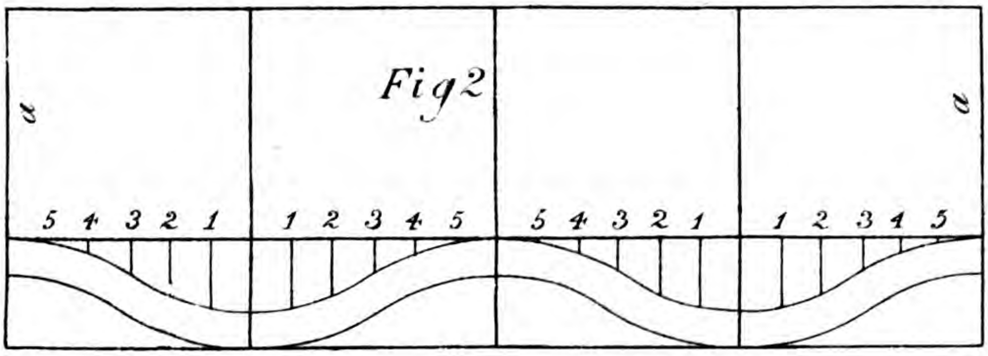


Fig 2

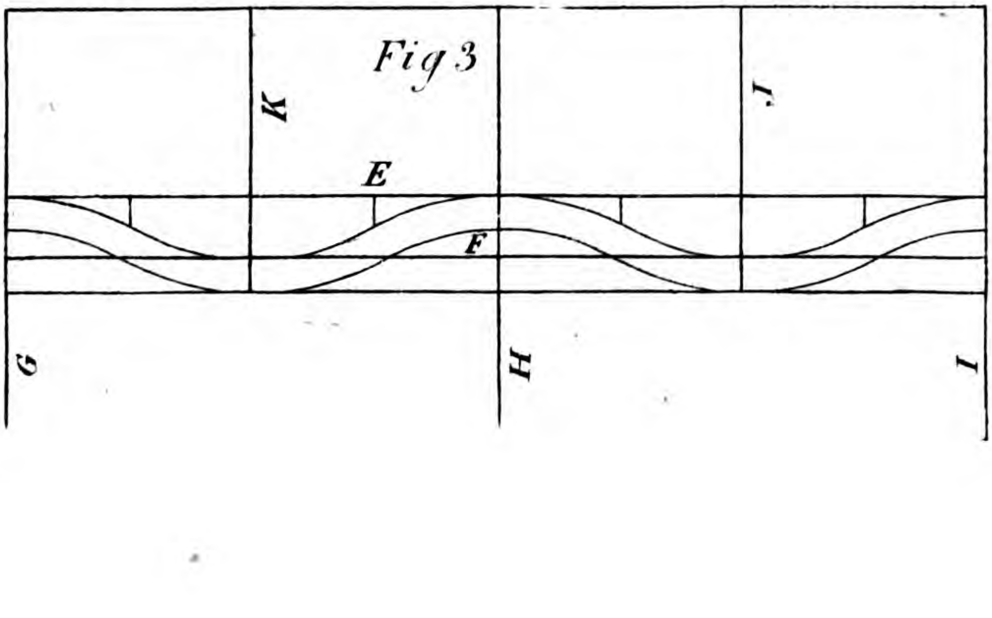


Fig 3

Get your plate or plates for the steam chest the length and width which you require, and mark it off into four equal parts as shown at fig. 2; then divide each of these into as many equal parts as you have divided the quarter-circle at B fig. 1. The lines from these points, 1,2,3,4,5, must be equal in length to the lines from the horizontal line A A to the top of the boiler numbered 1,2,3,4,5. You can then with a thin batten draw the line from point to point, which will give you the required shape of the steam chest before being bent. You must then allow for the flange. Lines A A fig. 2 must be the length of the short side of the steam chest.

The second and most simple method is to strike out the end of the boiler, with the steam chest on the top, and draw a horizontal line C fig. 1 from the points where the steam chest rest on the boiler, and get the distance from that line to the top of the circle at D. You then get your plate for the steam chest and divide it into four equal parts: then draw the line E fig. 3 the distance from the top of the plate equal to the short side of the steam chest; then draw a parallel line F the same distance from the line E as the line D fig. 1 is long from line C to the top of boiler. From line E draw four short lines half the length in the centre of each of the four divisions. Extend lines G H I and set your trammel to any radius, taking line H as a centre, so as to catch line E and the points of the short lines in the middle divisions, and strike the centre curve. Do the same on lines G and I without altering the trammels; then go to the other side of the plate and take line J and K as centre. Continue the curves from the short lines, touching line F; from this curve line draw another one the width you require the flange.

If we were going to plate up a boiler according to fig. 4, with one edge of the plate inside and the other out, according to the dimensions before given, then the length of the outside edge of the plates would be 6 feet 5⅜ inches from centre to centre of rivet holes, and the length of the inside edge 6 feet 4 inches from centre to centre of rivet holes; lap must be allowed in both cases. But this is not quite enough, as the plates, when bent and put together in rings, must form the frustum of a cone, that they may be inserted one into the other, and to do this you must proceed as follows:—

Get your plate and draw lines A B fig. 5 parallel to each other the required width, then draw the perpendicular line C. Now, suppose that line A to be the long side of the plate and line B the short side. Line A is to be 6 feet $5\frac{3}{8}$ inches from centre to centre of rivet holes, then mark off on line 3 feet $2\frac{11}{16}$ inches each side of the centre line C. The short line B is 6 feet 4 inches, and in this case mark of 3 feet 2 inches each side of line C, then draw lines E D from the points of measurement named; this will then form the taper plate.

We shall next require to find the camber. Take a square and place the short end of it even with line E, the corner of it resting on the upper corner of the plate, and strike line F. Where line F intersects line C, one half of the distance between line F and line A is the correct camber. Now bend a rod of iron so that it will catch the lines on the corners, and the height of the camber in the centre of plate, and strike the curve as shown by the dotted lines. Make the other side of the plate parallel to this and the template is complete.

In punching the plates for a telescopical boiler you must punch one side and one end of the plates and turn the plates over to punch the other side and end, except the back and tier, which should be punched according to the first rule, page 8.

EGG END TEMPLATE.

If we were going to make a template for the egg end of a boiler we should proceed as follows:—Draw a straight line A B, fig. 6, now set your compasses to half the diameter of the

Fig 4

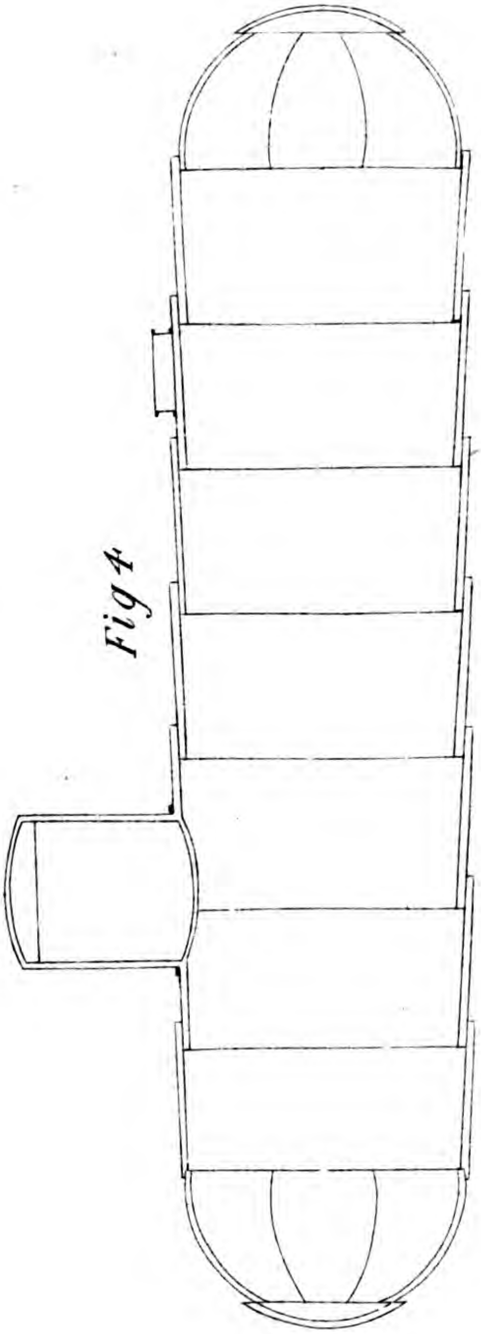
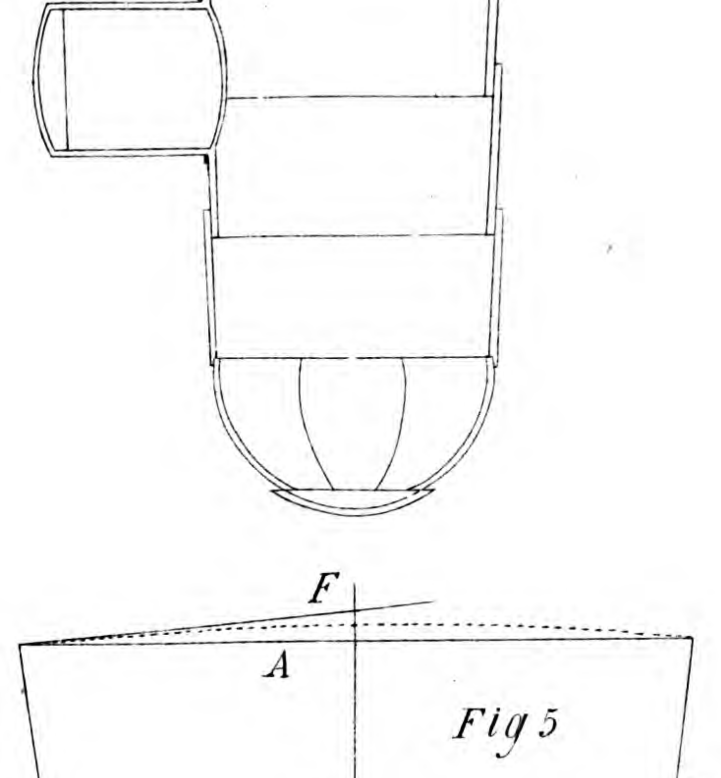


Fig 5



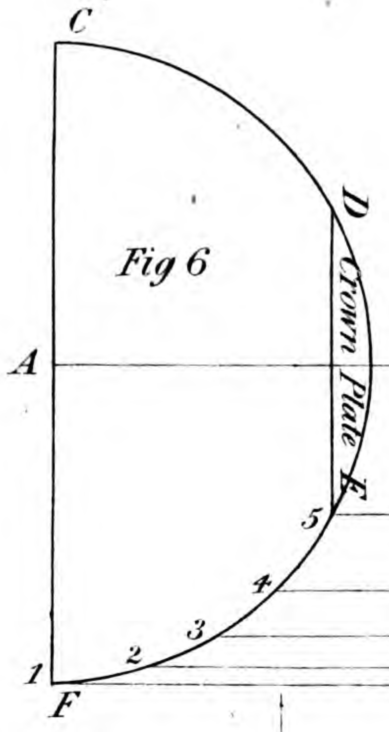


Fig 6

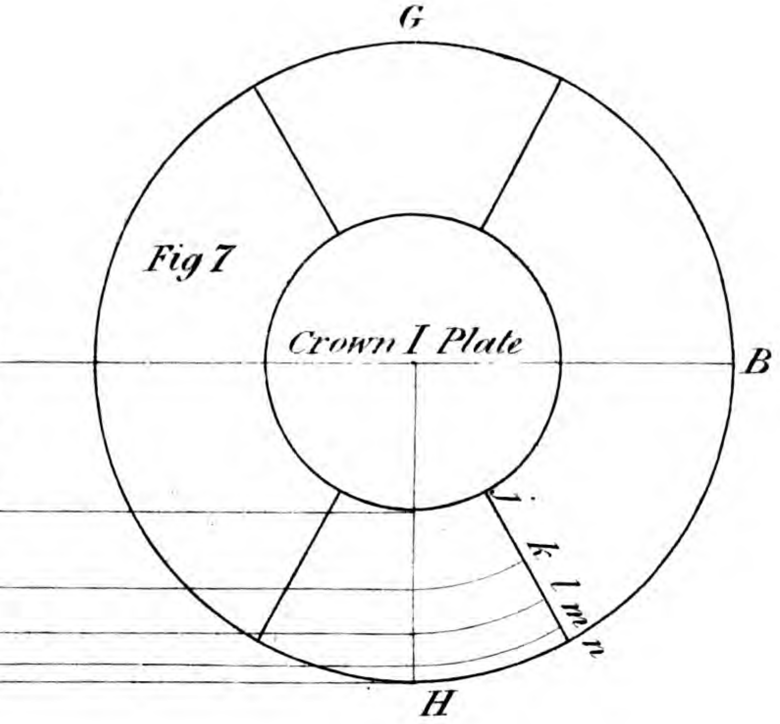


Fig 7

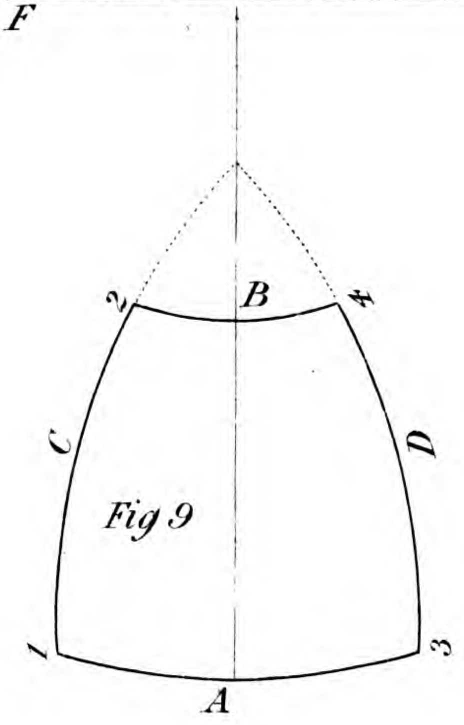


Fig 9

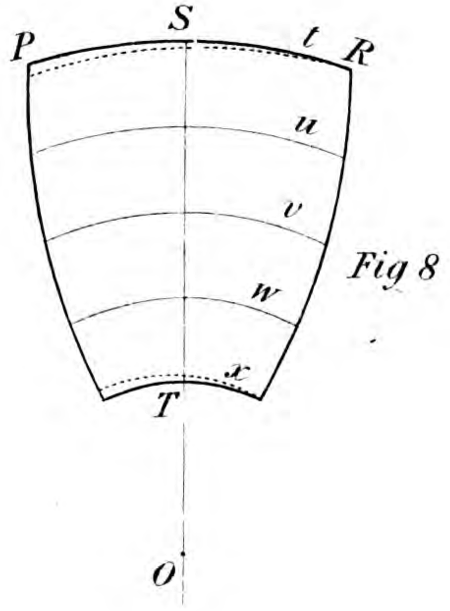


Fig 8

boiler, measuring the inside of the casing, then on any point on line A B describe the half circle C, D, E, F. Erect the perpendicular line from F to C, intersecting the centre at A. Now with the same radius divide the half circle into three equal parts, and from the points D to E draw a straight line, which will give you the crown plate. The curve line from C to D will give you the length of the other plates from centre to centre of rivet holes.

On the line A B, and with the same radius as before, describe the circle G B H, fig. 7; also the inner circle at one-half the diameter, being the size of the crown plate. Now divide the outer circle into as many parts as you intend to have plates in the boiler end, say 6 in this case, which is generally the number. You have next to divide the curved line from E to F, fig. 6, into any number of equal parts, and from the points 1, 2, 3, 4, 5 in the half circle, draw lines parallel with line A B, until they reach the centre line H; then with I as centre describe the arcs *j*, *k*, *l*, *m*, *n*. Then set the compasses to one-and-a-half the diameter of the boiler, and with O as centre describe the arc P R, fig. 8. Now measure off on the perpendicular line from S to T the length equal to the curved line between F and E, fig. 6, being $\frac{1}{6}$ the circumference of the diameter of the boiler end; now divide it into the same number of equal parts, and with O as centre, draw the arcs as shown, make the curved lines *t*, *u*, *v*, *w*, *x*, equal in length, each side the centre line, to those marked *j*, *k*, *l*, *m*, *n*, fig. 7, then through these points draw the curved lines on the sides of fig. 8. These lines give you the centre of the holes, then add the usual lap, 2¼ inches. The holes at the end of the template must correspond with those in the casing.

The inside edge of each of the end plates will require to be the thickness of the plate shorter than the other, on account of the other over-lapping it; it should be taken off each end of the plates, as shown by the dotted lines. The long and short edges must be carefully divided into the same number of parts to contain the same number of holes.

Another and more simple method of making the template is to take a thin plate of iron and draw a straight line through the centre of it, then take your trammels and set them to one-and-a-half the diameter of the boiler, and strike the curved line A, fig. 9. If the end is to be composed of six plates, then the line A must be $\frac{1}{6}$ the circumference of the boiler in length from centre of holes, one-half to be each side of the centre line. The centre line from A to B must also be $\frac{1}{6}$ the circumference of the boiler in length. Now with the same radius strike the curve lines C and D, and the lines from the points 1, 2, and 3, 4 must also be $\frac{1}{6}$ the circumference of the boiler in length, measuring them with the curve. For the radius of the small end set the trammels to one-and-a-half the radius of the crown plate. $1\frac{1}{4}$-inch must be allowed each side these lines for the lap. The inside lap must be the thickness of the plate shorter than the outside lap, as explained before.

This completes the template as far as the marking is concerned. Now cut the template out, leaving it only about 3 inches wide all round, get holes drilled in the four corners and the centres of lines A, C, and D. Now cut out two plates by this, and bend them as required, and when one of them is cold, heat the template in the furnace and bend it also to the same curve as the end plate; when this is done mark off the seven holes in each plate, and get them punched or drilled, and place them in their positions; you will then soon see if there is any alterations required; if so, do it so as to make the template quite correct, which, when done carefully, mark off the remaining holes in the template with a pair of spring dividers, and get them drilled; you will now use this template in the future.

Don't punch your holes before the plates are bent; if you do they will not be round after, and the job when complete will not be a satisfactory one.

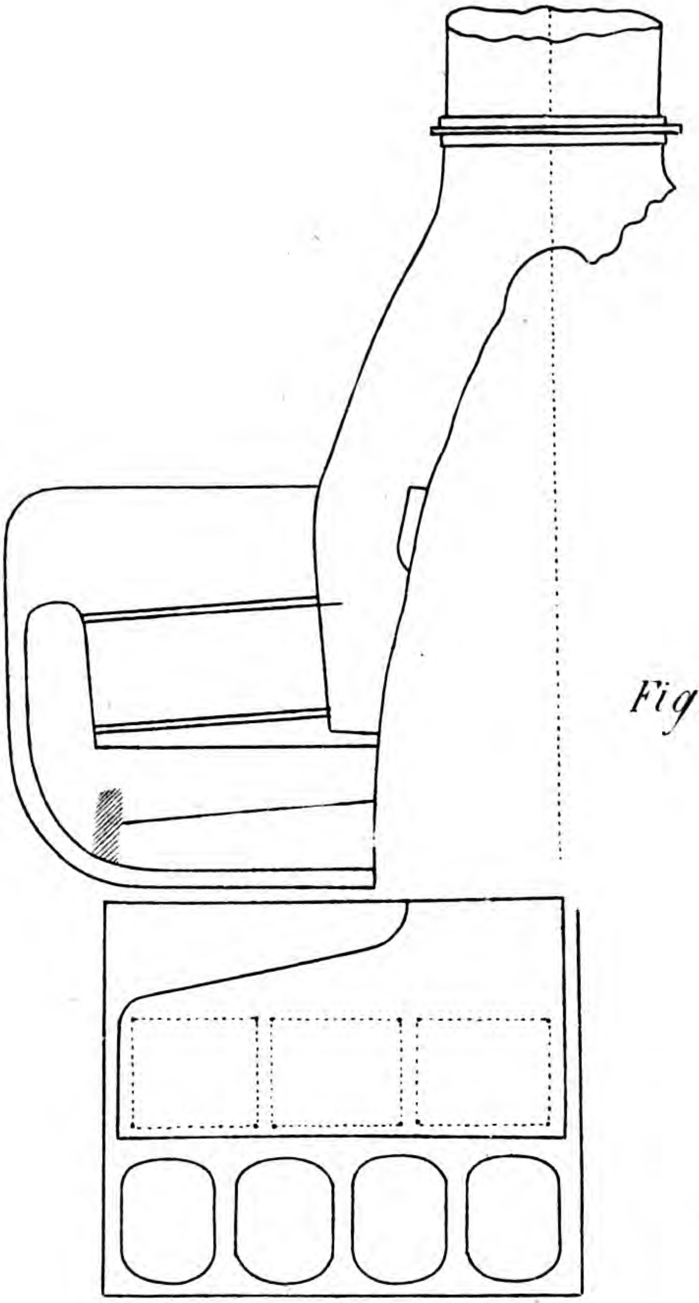


Fig 10

Fig 11

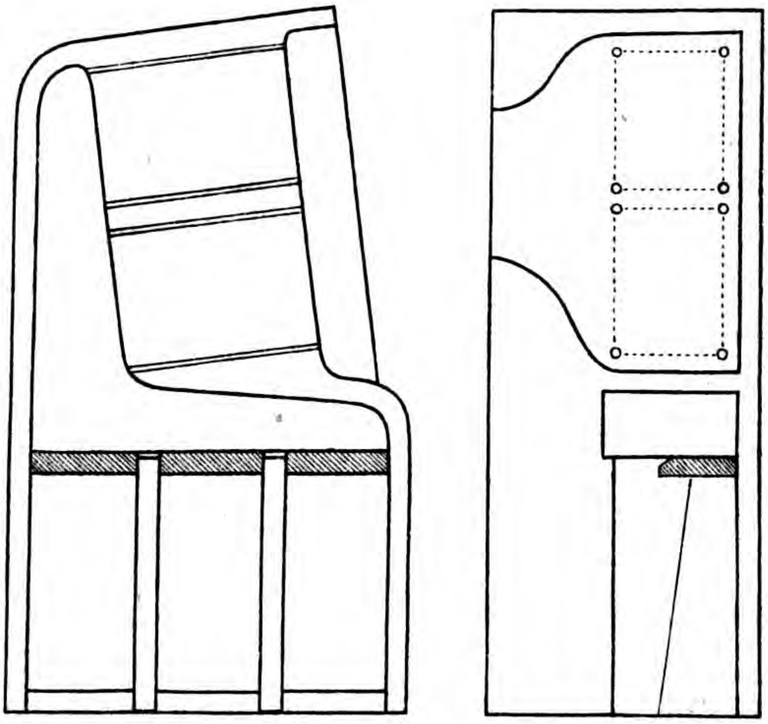
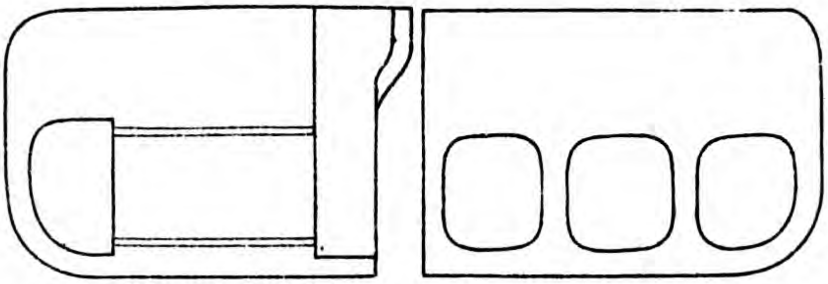


Fig 12



MARINE BOILER.*

As marine boilers vary so much in size and shape, according to the vessels for which they are intended, it is impossible to lay down any given rule for their construction. I shall therefore content myself with a slight description of them.

In all ships of war the boilers must be placed below the orlop-deck, or one foot below the water-line. The boilers are of two classes—namely, high and low, as shown by figs. 10, 11, 12. In very fine ships it is often a difficult matter to arrange the boilers to meet the requirements for great power. The arrangement is stokehole fore-and-aft, with furnaces athwart ship, with overhead return tubes; and for the low-class boilers furnaces running fore-and-aft, with tubes athwhart ship on the same level as furnaces.

For 400 nominal horse power the high-class boiler is adopted, the width of stokehole from front of furnaces being 10 feet, and the width of top of boilers 7 feet; the width from front of furnaces to back of boiler (in this case) 10 feet, height 11 feet, and length 12 feet 9 inches. And four boilers, each 100 horse power:—from top of boiler to top of flues not less than 3 feet 6 inches; so as to insure ample steam room, the area of fire-grate per horse power 18 square feet, and in some cases even more than this is demanded; area of funnel 10 square inches per horse power; from bottom of boilers to bottom of furnaces 3 feet 6 inches; the length of fire-grate should not exceed, if possible, 6 feet 6 inches, allowing for a dead plate 6 inches from front of boiler; the width of furnaces should not be less than 2 feet 6 inches, and certainly not exceed 3 feet 3 inches. It must be acknowledged by all that marine boilers should have as many furnaces as possible, bearing in mind that the length should not be out of all proportion to the width, so that the fireman may be able to keep the fires in proper trim.

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* See Weale's series, *Modern Workshop Practice*, on Marine Boilers, Sold by Crosley, Lockwood & Co., 7, Stationers' Hall Court.

For instance, some would place three furnaces in each boiler, 3 feet 5 inches broad, while others would have four furnaces, say 2 feet 7 inches broad. In the former they effect a saving of material—namely, two sides; and in the latter two additional sides are required and an extra water space, but with what result? The fire-box of a locomotive boiler—that is the sides and top exposed to the live coal—is the most effective heating surface. So it is with marine boilers. The most surface exposed to the live coal must be the best steam-producing-boiler, and in the act of firing less cold air is admitted, for there can be no doubt that with an opening of 3 feet 5 inches wide the body of air admitted by the furnace door and under side of firebars tends in a great measure to damp the other two fires.

The brass tubes are 2½ inches in external diameter, thickness No. 12 wire gauge, length in this instance 6 feet 6 inches, and the pitch of tubes 3½ inches; the average length of tubing per horse power equals 24 lineal feet.

Thus far the height of furnace is set off, and the height of boiler, and distance of top of flues from top of boiler; so now the designer may determine the top and bottom line of tubes, and allowance of half-an-inch per foot in length being the inclination of tubes.

The draughtsman will find it very convenient to rule a clear piece of parchment in squares according to the scale adopted, these squares representing the pitch of the tubes, as there are four boilers, each 100 horse power, and as the tubes are 6 feet 6 inches long:—

$$\frac{100 \times 24}{6{\cdot}5} = 369 \text{ tubes in each boiler.}$$

A little more can be given if necessary. Apply the parchment to the drawing, and it will at once determine the space required; an allowance must be made if the tube-plate is in two pieces. If the designer can get the amount of fire-grate in the space, this determines the length of boiler. For precaution he must run out the total heating surface, so as to have 18 square feet per horse power. The distance between furnaces 6 inches, and at sides 5 inches. The outer shell of boiler in the direction of furnaces should be quite flat; but around the boiler, at top and bottom of back, the plates can be curved as occasion may require. The fire-box width at top of tubes not less than 1 foot 6 inches. This is required so as to give room for the workman to make the tubes tight, or driving in the ferrules. The contents of steam room 4 cubic feet per horse power—while in a low boiler, taking up a length fore-and-aft 19 feet 6 inches, and 21 feet 6 inches of the beam, and 7 feet 3 inches high, the contents of steam room is about 6 cubic feet. This is for 150 horse power :—

Thickness of	Shell	$\frac{3}{8}$	of an inch.
,,	Bottom and bottom of Fronts...	$\frac{7}{16}$	,,
,,	Tube Plates	$\frac{5}{8}$	,,
,,	Furnaces	$\frac{7}{16}$	,,
,,	Uptake	$\frac{1}{2}$	,,

Angle Iron, 3 × 3 × $\frac{1}{3}$ at root.

The diameter of rivets, $\frac{3}{4}$ of an inch and 2 inches pitch. The plates should be ordered for the particular boiler required, and all the plates as far as possible even dimensions; this is obvious from the pitch of rivets. All the flat plates can be at once sent to the punching machine; no templating is required; the multiple punch and the travelling table perform their work in the most accurate manner, the edges of the plates being planed. Diameter of stays $1\frac{1}{4}$-inch, with screwed ends $1\frac{1}{2}$-inch diameter—this is to pass the stays easily from one side to the other; nuts inside and out; the pitch of stays 16 inches; the fire-bars of wrought iron, 3 inches deep, $1\frac{3}{8}$-inch at top and $\frac{1}{2}$-inch at bottom, with $\frac{1}{2}$-inch spaces between; inclination of fire-bars $1\frac{1}{4}$-inch to the foot.

STRENGTH OF PLATES.

It has been shewn by the result of experiments that ordinary boiler plates will not bear more than 23 tons to the square inch, and where the material is punched out for the reception of the rivets we must still further reduce the strength, and take 15 tons, or about 34,000 lbs. on the square inch, as the tenacity of the material or the pressure at which a boiler would burst.

By experiment it is found that the strength of riveted joints of boilers is only about one-half the strength of the plate itself, but taking into consideration the crossing of the joints, 33,000 lbs. may reasonably be taken as the tenacity of the riveted plates, or the bursting pressure of a cylindrical boiler.

The thickness of plates of cylindrical boilers should be in proportion to their diameter, for as a force tending to burst a boiler of a given length, and subject to a given pressure, varies simply as the diameter of the boiler; and as the resistance of the plates varies as their thickness, it follows that the thickness of the plates in order to resist a given pressure of steam, per square inch, must be in proportion to the diameter of the boiler. For example, two boilers, one 3 feet in diameter and the other 6 feet, and suppose each to be subject to a pressure of 40 lbs. on the square inch, in this condition it is evident that the area or number of square inches in the end of a 3 feet boiler is to that of 6 feet boiler as 1 to 4, and by a common process of arithmetic it will be found that the edges of the plates forming the cylindrical part of the 3 feet boiler are subject (at 40 lbs.) to a pressure of 40,712 lbs., upwards of 18 tons, whereas the plates of the 6 feet boiler have to sustain a pressure of 162,848 lbs., or 72 tons, which the force to which the boiler only one-half the diameter is exposed, and circumferences being only as 2 to 1, there is double the strain upon cylindrical plates of the large boiler. It follows if the forces at the same pressure be doubled in the large cylinder, that the thickness of the plates must also be doubled in order to sustain the same pressure with equal security, or what is the same thing, the 6 feet boiler must be worked at half the pressure in order to insure the same degree of safety as that attained in the 3 feet one at double the pressure. The relative power applied to cylinders of different diameters becomes more strikingly apparent when we reduce them to their equivalents of strain, per square inch, as applied to the ends and circumference of the boiler respectively. In the 3 feet boiler working at 40 lbs. pressure, we have a force equal to 720 lbs. pressure upon an inch width of plate, and one quarter of an inch thick, or 720 × 4 = 2,880 lbs. force, per square inch, upon every point of the circumference of the boiler.

Now compare this with the actual strength of the riveted plates themselves, which taken as before, at 34,000 lbs. on the square inch, we arrive at the ratio of pressure as applied to the strength af circumference.

These deductions appear to be true in every case as regards the resisting powers of cylindrical boilers, to a force radiating in every direction from the axis towards the circumference, but the same law is, however, not maintained when it applies to the ends. Now to prevent this let us take the 3 feet boiler, where we have about 113 inches on the circumference, and upon this circular line of connection we have at 40 lbs. to the square inch to sustain a pressure of 18 tons, which is equal to a strain of 360 lbs. acting longitudinally upon every inch of the boiler's circumference; apply the same to a 6 feet boiler with a circumference or line of connection equal to 226 inches, and we shall find it exposed to exactly four times the force, or 72 tons, but in this it must be borne in mind that the circumference is doubled, and consequently the strain, instead of being in the quadruple ratio, is only doubled, or a force equal to 720 longitudinally as before upon every inch of the circumference of the boiler. Again, if we refer to the comparative merits of the plates composing cylindrical vessels subject to internal pressure, they will be found in that anomalous condition, that the strength in their longitudinal direction is twice that of the plates in the curvilinear direction. This appears by a comparison of the two forces, wherein we have shewn the end of the 3-feet boiler at 40 lbs. internal pressure sustain 360 lbs. of longitudinal strain upon each inch of a plate a quarter of an inch thick, whereas plenty of the same thickness have to bear in the curvilinear direction a strain of 720 lbs. This difference of strain is a difficulty not easily overcome, and all that we can accomplish in this case will be to exercise a sound judgment in crossing the joints, in the quality of the workmanship, and the distribution of the material. For the attainment of these objects the following table, which exhibits the proportional strength of cylindrical boilers from 3 to 8 feet in diameter, may be useful.

Table of equal strength in cylindrical boilers, from 3 to 8 feet, shewing the thickness of metal in each respectively at a pressure of 450 lbs. per square inch.

Diameter of Boilers.	Thickness of Plates in decimal parts of an inch.	Diameter of Boilers.	Thickness of Plates in decimal parts of an inch.
FT. INS.		FT. INS.	
3 0	·250	6 0	·500
3 6	·291	6 6	·541
4 0	·333	7 0	·583
4 6	·376	7 6	·625
5 0	·416	8 0	·666
5 6	·458		

(Bursting Pressure of the above is 45 lbs.)

Bursting pressure equivalent to the ultimate strength of the riveted joints as deducted from experiment, 34,000 lbs. to the square inch.

It has been found by actual experiment that good English forged iron will bear a strain of 25 tons to the square inch—

that a bar 1 inch square, or a plate of wrought iron containing 1 inch of sectional area, will require 25 tons or 36,000 lbs. to wrench it asunder; but Mr. Fairbairn states that plates when riveted together are in strength (from the fact that nearly one-third of the material is punched out for the reception of the rivets) much reduced, and therefore he takes 34,000 lbs. as equal to the strength of riveted plates containing 1 inch of sectional area.

The following table shows what different diameters and thicknesses of plates are required for a safe working pressure—viz.: one-sixth of their actual strength when made of good material and workmanship.

It should be observed that the ends, if properly made and stayed, have only one-half the pressure exerted upon them that the diameter has, so that they have only to resist one-twelfth of their strength.

Diameter of Boiler.		Working Pressure for ⅜-in. Plates.	Bursting Pressure for ⅜-in. Plates.	Working Pressure for ½-in. Plates.	Bursting Pressure for ½-in. Plates.
FT.	INS.	LBS.	LBS.	LBS.	LBS.
3	0	118	708¼	157½	944¼
3	3	109	533¾	145¼	871¾
3	6	101	607	134¾	809½
3	9	94½	566½	125¾	755½
4	0	88½	521	118	708¼
4	3	83¼	500	111	666½
4	6	78¾	472	104¾	629½
4	9	74½	447¼	99¼	596¼
5	0	70¾	425	94¼	566½
5	3	67¼	404¾	89⅜	539½
5	6	64¾	386¼	85¾	515
5	9	61½	369½	82	492¾
6	0	59	354	78¾	472
6	3	56½	340	75½	453¼
6	6	54¼	326¾	72½	435¾
6	9	52¼	314¾	69¾	419½
7	0	50½	303½	67¼	404½
7	3	48¾	293	65	396¾
7	6	47	283¼	62¾	377½
7	9	45½	274	60¾	365½
8	0	44	265¾	59	354
8	3	42¾	257½	57	343¼
8	6	41½	250	55½	333¼

Rule for ⅜-inch plates:—Divide 4·250 by the diameter of the boiler in inches: the quotient is the working pressure, being one-sixth the strength of the joints.

Rule for ½-inch plates:—Divide 566·6 by the diameter of the boiler in inches, and the quotient will be the greatest pressure that the boiler should be worked at when new—that is at one-sixth the actual strength of the punched iron:—

$$\begin{array}{r} 12)\underline{5666{\cdot}6} \\ 472{\cdot}2 \end{array} \text{ Answer.}$$

RIVETED JOINTS.

A series of tests to ascertain the strength of riveted joints, originating from the explosion of two new boilers at Blackburn in the year 1874, has been carried on at intervals since that time, and is now completed—so far, at least, as it has been thought necessary to go at present.

The following tables show in a condensed form the results of the tests of lap and butt joints single and double riveted, varying in pitch and size of rivets. The *nominal* thickness of plate and size of rivets are here given; the calculations have all been made from exact measurements.

The figures in the fifth column shew the ratio of strength of the joints to that of the solid plates; for example, taking the first joints tested, where the ratio given in the table is 38·9, and assuming the tensile strength of the plate to be 20 tons per square inch, the strength of the joint would be—

$$\frac{20\times 38{\cdot}9}{100}=7{\cdot}78 \text{ tons per square inch.}$$

The ratio of strength is not however constant, but varies with the ductility of the plate—in lap joints at least—as will be explained hereafter. Therefore in calculating the strength of a boiler, or any structure made with riveted joints, it is necessary to take into account the ductility as well as the tensile strength of the plate.

LAP JOINTS, SINGLE RIVETED.

No of Tests.	Nominal thickness of Plate in inches.	Nominal diameter of Rivets in inches.	Pitch of Rivets in inches.	Mean ratio of Joint to solid Plate, percentage.	REMARKS.		
					PLATES.	RIVET HOLES.	HOW JOINTS FAILED.
2	7/16 *f*	13/16	2	38·9	Unannealed.	Punched.	Plate broken.
2	,,	,,	,,	45·7	Annealed.	Ditto.	Ditto.
2	7/16	3/4	2 1/8	39·1	Unannealed.	Drilled.	Rivets sheared.
2	,,	,,	,,	39·7	Ditto.	Punched.	Ditto.
2	,,	,,	,,	41·8	Annealed.	Ditto.	Ditto.
2	,,	3/4 *b*	2	40·1	Unannealed.	Ditto.	In one, plate broken ; in the other, rivets sheared.
2	,,	,,	,,	44·2	Annealed.	Ditto.	Rivets sheared.
2	,,	,,	,,	41·6	Unannealed.	Drilled.	Ditto.
2	,,	3/4 *f*	,,	47·1	Ditto.	Punched.	In one part of plate broken and two rivets sheared ; in the other, all rivets sheared and plate cracked at rivet holes.
2	,,	3/4 *b*	,,	60·1	Ditto, joint diagonal angle of 45°.	Ditto.	In one, plate broken ; in the other, rivets sheared.
2	1/2	13/16	2	40·7	Unannealed.	Ditto.	Plate broken.
2	,,	,,	2 1/8	43·9	Annealed.	Ditto.	Rivets sheared.
2	,,	,,	,,	39·4	Unannealed.	Ditto.	Rivets sheared and plate cracked.
2	,,	,,	,,	39·0	Ditto.	Drilled.	Rivets sheared.
2	1/4	9/16	1 1/2	50·6	Ditto.	Punched.	In one, rivets all sheared and plate cracked at holes ; in the other, half of the rivets sheared and half the plate broken.
2	1/4	1/2	1 1/2	50·9	Unannealed, breaking joint one hole, or 1 1/2 inch.	Ditto.	Rivets all sheared.
2	,,	1/2	,,	55·5	Unannealed, breaking joint five holes, or 7 1/2 inches.	Ditto.	Rivets of one seam sheared and adjoining plate torn.
2	,,	,,	,,	56·2	Unannealed, breaking joint nine holes, or 13 1/2 inches.	Ditto.	Ditto ditto.
2	7/16	3/4	2 1/8	44·9	Unannealed, breaking joint one hole, or 2 1/8 inches.	Ditto.	Rivets all sheared.
2	,,	,,	,,	48·3	Unannealed, breaking joint six holes, or 12 3/4 inches.	Ditto.	Rivets of one seam sheared; all the other rivets partly sheared and solid plate slightly torn.
2	1/2	13/16	2	54·7	Unannealed, breaking joint six holes, or 12 inches.	Ditto.	In one, plates torn and one rivet sheared ; in the other, rivets of one seam sheared and the adjoining plate torn.

Note.—The dimensions marked *f* were *fully* and those marked *b* *barely* the sizes given.

LAP JOINTS, DOUBLE RIVETED.

No. of Tests.	Nominal thickness of Plates in inches.	Nominal Diameter of Rivets in inches.	Pitch of Rivets in inches.	Mean ratio of Joint to solid Plate, percentage.	REMARKS.		
					PLATES.	RIVET HOLES.	HOW JOINTS FAILED.
2	$\frac{7}{16}f$	$\frac{13}{16}$	2	54·5	Unannealed.	Punched, "Zigzag riveting."	Plate broken.
2	"	"	"	58·1	Annealed.	Ditto ditto.	Ditto.
2	$\frac{7}{16}$	"	$2\frac{1}{2}$	59·7	Unannealed.	Ditto ditto.	Ditto.
2	"	$\frac{3}{4}f$	$2\frac{1}{2}$	66·1	Ditto.	Ditto ditto.	Ditto.
2	"	$\frac{13}{16}$	$2\frac{3}{4}$	61·0	Ditto.	Ditto ditto.	Ditto.
2	$\frac{1}{2}$	$\frac{13}{16}$	3	60·3	Ditto.	Ditto ditto.	Ditto.
2	"	$\frac{7}{8}$	3	64·9	Ditto.	Drilled, ditto.	Ditto.
2	$\frac{7}{16}$	$\frac{5}{8}$	$2\frac{1}{8}$	53·2	Ditto.	Punched, ditto.	Rivets sheared & plates cracked at holes.
2	$\frac{7}{16}$	$\frac{3}{4}$	$2\frac{1}{8}$	62·9	Ditto.	Ditto "Chain riveting."	Plate broken.
2	$\frac{1}{2}$	$\frac{15}{16}$	$2\frac{1}{4}$	61·6	Ditto.	Ditto ditto.	Ditto.

NOTE —The dimensions marked *f* were *fully*, and those marked *b* *barely* the sizes given.

BUTT JOINTS, SINGLE RIVETED.

No. of Tests.	Nominal thickness of Plates in inches.	Nominal Diameter of Rivets in inches.	Pitch of Rivets in inches.	Mean ratio of Joint to solid Plate, percentage.	REMARKS.		
					PLATES.	RIVET HOLES.	HOW JOINTS FAILED.
2	$\frac{7}{16}$	$\frac{13}{16}$	2	56·5	Unannealed.	Punched.	Plate broken.
2	"	$\frac{3}{4}$	2	54·4	Ditto.	Ditto.	Ditto.
2	"	"	"	58·5	Ditto.	Drilled.	Ditto.
2	"	"	"	57·9	Annealed.	Punched.	Ditto.
2	"	$\frac{11}{16}$	$2\frac{1}{8}$	55·1	Unannealed.	Drilled.	Ditto.
2	$\frac{1}{2}$	$\frac{3}{4}$	$2\frac{1}{4}$	51·5	Ditto.	Ditto.	Ditto.
2	$\frac{7}{16}$	$\frac{11}{16}$	$2\frac{1}{8}$	66·1	Ditto, breaking joint 12 inches.	Ditto.	Ditto.
2	$\frac{1}{2}$	$\frac{3}{4}$	$2\frac{1}{4}$	60·5	Ditto ditto.	Ditto.	Ditto.

BUTT JOINTS, DOUBLE RIVETED.

No. of Tests.	Nominal thickness of Plates in inches.	Nominal Diameter of Rivets in inches.	Pitch of Rivets in inches.	Mean ratio of Joint to solid Plate, per centage.	REMARKS.		
					PLATES.	RIVET HOLES.	HOW JOINTS FAILED.
2	7/16	13/16	2½	61·6	Unannealed.	Punched, "Zig-zag riveting."	Plate broken.
2	"	"	2¾	64·8	Ditto.	Ditto ditto.	Ditto.
2	½	15/16	3	67·0	Ditto.	Ditto ditto.	Ditto.
2	7/16	⅝	2½	65·6	Ditto.	Ditto ditto.	Ditto.
2	"	"	3	66·9	Ditto.	Ditto ditto.	Ditto.
2	½	"	"	62·4	Ditto.	Ditto ditto.	Ditto.
4	"	"	"	65·0	Ditto.	Drilled, ditto.	In one, rivets sheared and plate cracked; in the others, plates broken.
	½	⅝	3	69·2	Ditto, joint diagonal.	Ditto ditto.	Plate broken.
2	"	¾	"	63·3	Ditto.	Ditto ditto.	Ditto.
2	7/16 "	⅝	2⅛	67·2	Ditto.	Punched, "Chain rvtng,"	Ditto.
2	½	¾	2¼	66·2	Ditto.	Drilled, ditto.	Ditto.
2	"	"	"	74·7	Ditto, breaking joint 7 holes, or 14 inches.	Ditto ditto.	Ditto.

LAP JOINTS, SINGLE RIVETED.

The riveting of the lap joints first tested was precisely similar to that of the exploded boilers above referred to; the quality of the iron both for the plates and rivets was good, and the workmanship fully equal to if not above the average. The results obtained may therefore be relied upon as showing accurately the ultimate strength of riveted joints for boiler work as generally constructed.

In calculating the strength of a boiler, it has hitherto been the practice to estimate the strength of single riveted joints at 56 per cent. of the tensile strength of the solid plate, whereas it now appears that, with joints as usually proportioned, it does not exceed 39 per cent., unless the plates have been annealed.

The best proportioned single riveted lap joint with $\frac{7}{16}$-inch plates was found to be that with rivet holes punched fully $\frac{3}{4}$-inch diameter and 2-inch pitch, giving 47 per cent. as the ratio of joint to solid plate. The ratio of 60·1 per cent. was obtained with the same size and pitch of rivets when the joint was diagonal, this increase of strength being evidently attributable to the increased sectional area of plate and rivets in proportion to the breadth of the plate. For instance, in a plate 12 inches wide with rivets 2 inch pitch, there would only be six rivets in the joint if it were straight, that is, at right angles to the line of strain; but if diagonal, at an angle of 45°, there would be eight rivets, and the plate area would likewise be increased. With $\frac{1}{2}$-inch plates unannealed the best result was obtained with rivet holes punched $\frac{13}{16}$-inch diameter and 2-inch pitch, giving 40·7 per cent. as the ratio of joint to solid plate. With $\frac{1}{4}$-inch plate the ratio of joint to solid plate was 50·6 per cent., or 10 per cent. more than with plates double the thickness. It appears, therefore, that in lap joints the ratio of strength between joint and solid plate decreases as the thickness of plate increases. This no doubt is mainly, if not wholly due to the bending or cross strain to which all lap joints are subjected,—this cross strain increasing with the thickness of the plates. Where plates have been annealed they are less affected by this cross strain on account of their greater ductility, which will account for the higher ratio of joint to solid plate in such cases, as shewn in the Table.

The tests made to ascertain what additional strength is obtained by arranging the plates to "break joint" shewed a gain of 14 per cent. with $\frac{1}{2}$-inch plates, the distance between the seams being 12 inches. With $\frac{1}{4}$-inch and $\frac{7}{16}$-inch plates the increase of strength was considerably less, but as in these cases the rivets were rather too small for the pitch, and were consequently sheared, the maximum strength may not have been obtained. The increase of strength due to "breaking joint" will evidently be dependent on the length of the joint, that is to say, a boiler of which the longitudinal seams are continuous from one end to the other (the ordinary mode of construction until within recent date) must evidently be materially weaker than one where the seams break joint at each successive ring.

LAP JOINTS, DOUBLE RIVETED.

The double riveted lap joints first on the list, with rivet holes punched $\frac{13}{16}$-inch in diameter, and arranged "zigzag" 2 inches from centre to centre, were also precisely similar to those of the Blackburn boilers, and represent the double riveted lap joints as usually constructed at that time. These were supposed to be capable of bearing a stress equal to 70 per cent. of the tensile strength of the plate, whereas these tests prove that the ultimate stress with unannealed plates is only 54·5 per cent. By increasing the pitch to $2\frac{1}{2}$ inches for $\frac{7}{16}$-inch plates, and making the rivet holes $\frac{3}{4}$-inch diameter, a considerable increase of strength was obtained, the ratio of joint to solid plate rising to 66·1 per cent. With $\frac{1}{2}$-inch plate and rivet holes drilled $\frac{7}{8}$-inch diameter, 3 inches pitch "zigzag," the ratio was found to be 64·9 per cent.

BUTT JOINTS, SINGLE RIVETED.

The butt joints, it will be observed, show considerably more strength than the lap joints corresponding in size and pitch of rivets. The reason for this is obvious; in the first place the plates in a butt joint are subjected to a direct strain without any cross bending, and in the second place the rivets are in "double shear," and therefore capable of bearing double the stress they would bear in a lap joint, where they are only in "single shear." Such being the case, it is evident that in a butt joint the size of the rivets may be reduced, and any reduction in size of rivets will be attended with an increase in the sectional area of plate between the rivet holes. From this a considerable increase of strength in the joint might have been anticipated, but the tests show that the strength of a butt joint does not increase in direct proportion to the increased sectional area of plate. On the contrary, an excess of strength in the rivets (within certain limits) makes a stronger joint than when the size and pitch of the rivets are so proportioned that the shearing stress of the rivets equals the breaking stress of the plate. This increase of strength in the joint appears to be attributable to the adhesion or friction between the surfaces of the plate and straps, which must increase with the size of the rivets and the amount of contraction in cooling after riveting. The advantage of extra strength in the rivets will be seen by comparing the joints made with $\frac{7}{16}$-inch plates and drilled holes, the holes being in the one case $\frac{3}{4}$-inch diameter and 2 inches pitch, in the other $\frac{11}{16}$-inch diameter and $2\frac{1}{8}$ inches pitch. In both cases the joints failing from fracture of the plates showed that the rivets were stronger than the plates, but the greater sectional area of plate with the smaller rivets and wider pitch made the joint weaker in the proportion of 55·18 to 58·5. The tests made to ascertain the effect of breaking joint showed a gain of about 11 per cent. where the plates were $\frac{7}{16}$-inch thick, but only 9 per cent. with $\frac{1}{2}$-inch plates, the strength of joint with the former being 66·15 per cent. of the solid plate, and with the latter 60·58 per cent.

If the single riveted butt joints, with $\frac{13}{16}$ inch rivets and 2 inches pitch, be compared with the single riveted lap joints of the same pitch and size of rivets, it will be seen that the relative strength of the joints was as 56·5 to 38·9, and compared with the double riveted lap joints of same pitch and size of rivets, as 56·5 to 54·5, so that, in fact, with rivets of the same size and pitch, and the same thickness of plate, a single riveted butt joint is stronger than a double riveted lap joint.

BUTT JOINTS, DOUBLE RIVETED.

The effect of adhesion is well illustrated in the double riveted butt joints; for instance, in the joints made of $\frac{1}{2}$-inch plates, with rivet holes punched 3 inches pitch, where the rivets were $\frac{15}{16}$-inch diameter, with a sectional area (calculating for "double shear") more than double the net sectional area of plate between the rivet holes, the ratio of joint to solid plate was 67 per cent.; whereas, with rivets $\frac{5}{8}$-inch diameter, the sectional area of which (calculated in the same way) was as nearly as possible equal to that of the plate between the rivet holes, the ratio of joint to solid plate was only 62·4 per cent. In each case the joint failed from fracture of the plate, thus proving that even the $\frac{5}{8}$-inch rivets were stronger than the plates. With drilled holes $\frac{5}{8}$-inch diameter and 3 inches pitch in $\frac{1}{2}$-inch plates, the rivets and plate were as nearly as possible equal in strength, as shewn by one of the joints failing from shearing of the rivets with slight fracture of the plate at the rivet holes, and the others from fracture of the plates. It will also be seen that with rivets of the same size and pitch, but thinner plates, the latter being only $\frac{7}{16}$-inch thick, the excess of strength in the rivets made a stronger joint, the ratio of joint to solid plate rising to 66·9 per cent. The diagonal joint with the same pitch and size of rivets showed a further increase of 2·3 per cent., the ratio of joint to solid plate being 69·2 per cent. The superiority of "chain-riveting," or arranging the rivets in parallel lines instead of "zigzag," was clearly proved; for it will be observed that in the joints made of $\frac{7}{16}$-inch plates with $\frac{5}{8}$-inch rivets and $2\frac{1}{8}$-inches pitch "chain-riveted," the ratio of joint to solid plate was 67·2 per cent.; whereas with plates of the same thickness and rivets of the same size arranged "zigzag," with 3 inches pitch, the ratio was only 66·9 per cent.; and, again, comparing the joints made of $\frac{1}{2}$-inch plates and $\frac{3}{4}$-inch rivets, the relative strength of the joints, "chain-riveted" and "zigzag," was as 66·2 to 63·3, the former being $2\frac{1}{4}$ inches and the latter 3 inches pitch. It will thus be seen that by "chain-riveting" equal, if not greater strength may be obtained with a smaller pitch, an advantage of no small importance as regards calking and making a steam-tight joint.

The series of tests concluded with two experiments, to ascertain the effect of arranging the plates to "break-joint" seven holes or 14 inches apart; the plates were $\frac{1}{2}$-inch thick, the rivet holes for the chain riveted seams $\frac{3}{4}$-inch diameter and $2\frac{1}{4}$-inch pitch, those for the intervening single riveted lap joint $\frac{13}{16}$-inch diameter and 2 inches pitch, all drilled. When tested, both joints failed from fracture of plate at the rivet holes. In the one case the ratio of joint to solid plate was 74·3, and in the other 75·2 per cent., giving a mean of 74·7 per cent.

It therefore appears that for steam boilers made of iron plates $\frac{1}{2}$-inch thick to work at high pressures, the best proportioned and strongest joint is the butt joint "chain-riveted," with rivet holes drilled $\frac{3}{4}$-inch diameter and $2\frac{1}{4}$-inch pitch; the strength of which may be approximately estimated at 75 per cent. of the tensile strength of the plate.

RIVETS.

The rivets used for the whole of these joints were made of scrap iron, specimens of which were tested, and the average tensile strength of twelve different pieces was found to be 22·6 tons per square inch. Taking the mean of all the tests with single riveted lap joints where the rivets were sheared, gave the following results :—

	Number of tests.	Mean shearing stress per sq. in. in tons.
Plates unannealed, holes drilled ...	6	18·10
" " " punched...	12	18·24
" annealed " "	6	18·43

From the above it appears that as regards liability to shearing, it makes little difference whether the plates are annealed or unannealed, or whether the rivet holes are punched or drilled.

The shearing stress of steel rivets, as ascertained by Mr. Kirkaldy in some tests made for the Bolton Iron and Steel Company, was shown to be 24·5 tons per square inch. If, therefore, steel rivets were substituted for iron, the size might be reduced in proportion to their extra strength; and as this would leave a larger sectional area of plate between the holes, a stronger joint would be obtained. But it will naturally occur to anyone who gives the subject consideration, that if there be an advantage in using steel rivets, there must be a further advantage in using steel plates, inasmuch as these are nearly 50 per cent. stronger than iron,—the tensile strength of Bessemer plates suitable for boilers being about 30 tons per square inch, whereas that of iron plates is only from 20 tons to 22 tons per square inch. There has, however, until recently been much uncertainty as to the quality of Bessemer plates, and also considerable extra cost as compared with iron,—two objections which have greatly checked the introduction of steel plates. These objections need no longer exist, as with greater experience the makers of Bessemer plates, or at least some of them, are now able to supply plates suitable for boilers at a very moderate price, and with as much, if not more, certainty as to quality than any iron plates. The tests to which the makers allow the steel plates to be subjected are conclusive as to their quality, and are as follows:—Their tensile strength shall be from 30 to 32 tons per square inch; and every plate shall be of such quality that a strip cut off any part of it shall, after being heated red hot and plunged in cold water, be bent cold to a radius equal to one-and-a-half times the thickness of the plate without any signs of fracture. It need hardly be said that plates capable of bearing this severe test may be used with perfect confidence for steam boilers, and are very far superior to the iron plates generally used for this purpose.

CIRCUMFERENCE AND AREAS OF CIRCLES.

Diameter in Inches.	Circumference in Feet and Inches	Area in Square Inches	Diameter in Inches.	Circumference in Feet and Inches.	Area in Square Inches
$\frac{1}{16}$	·196	·0030	$4\frac{7}{8}$	1 $3\frac{1}{4}$	18·665
$\frac{1}{8}$	·392	·0122	5	1 $3\frac{5}{8}$	19·635
$\frac{3}{16}$	·589	·0276	$5\frac{1}{8}$	1 $4\frac{1}{8}$	20·629
$\frac{1}{4}$	·785	·0490	$5\frac{1}{4}$	1 $4\frac{1}{2}$	21·647
$\frac{5}{16}$	·981	·0767	$5\frac{3}{8}$	1 $4\frac{7}{8}$	22·690
$\frac{3}{8}$	1·178	·1104	$5\frac{1}{2}$	1 $5\frac{1}{4}$	23·758
$\frac{7}{16}$	1·374	·1503	$5\frac{5}{8}$	1 $5\frac{5}{8}$	24·850
$\frac{1}{2}$	1·570	·1963	$5\frac{3}{4}$	1 6	25·967
$\frac{9}{16}$	1·767	·2485	$5\frac{7}{8}$	1 $6\frac{7}{8}$	27·108
$\frac{5}{8}$	1·963	·3068	6	1 $6\frac{3}{4}$	28·274
$\frac{11}{16}$	2·159	·3712	$6\frac{1}{8}$	1 $7\frac{1}{4}$	29·464
$\frac{3}{4}$	2·356	·4417	$6\frac{1}{4}$	1 $7\frac{5}{8}$	30·679
$\frac{13}{16}$	2·552	·5185	$6\frac{3}{8}$	1 8	31·919
$\frac{7}{8}$	2·748	·6013	$6\frac{1}{2}$	1 $8\frac{3}{8}$	33·183
$\frac{15}{16}$	2·945	·6903	$6\frac{5}{8}$	1 $8\frac{3}{4}$	34·471
1	$3\frac{1}{8}$	·7854	$6\frac{3}{4}$	1 $9\frac{1}{8}$	35·784
$1\frac{1}{8}$	$3\frac{1}{2}$	·9940	$6\frac{7}{8}$	1 $9\frac{1}{2}$	37·122
$1\frac{1}{4}$	$3\frac{7}{8}$	1·227	7	1 10	38·484
$1\frac{3}{8}$	$4\frac{1}{4}$	1·484	$7\frac{1}{8}$	1 $10\frac{3}{8}$	39·871
$1\frac{1}{2}$	$4\frac{5}{8}$	1·767	$7\frac{1}{4}$	1 $10\frac{3}{4}$	41·282
$1\frac{5}{8}$	$5\frac{1}{8}$	2·074	$7\frac{3}{8}$	1 $11\frac{1}{8}$	42·718
$1\frac{3}{4}$	$5\frac{1}{2}$	2·405	$7\frac{1}{2}$	1 $11\frac{1}{2}$	44·178
$1\frac{7}{8}$	$5\frac{7}{8}$	2·761	$7\frac{5}{8}$	1 $11\frac{7}{8}$	45·663
2	$6\frac{1}{4}$	3·141	$7\frac{3}{4}$	2 $0\frac{3}{8}$	47·173
$2\frac{1}{8}$	$6\frac{5}{8}$	3·546	$7\frac{7}{8}$	2 $0\frac{3}{4}$	48·707
$2\frac{1}{4}$	7	3·976	8	2 $1\frac{1}{8}$	50·265
$2\frac{3}{8}$	$7\frac{3}{8}$	4·430	$8\frac{1}{8}$	2 $1\frac{1}{2}$	51·848
$2\frac{1}{2}$	$7\frac{3}{4}$	4·908	$8\frac{1}{4}$	2 $1\frac{7}{8}$	53·456
$2\frac{5}{8}$	$8\frac{1}{4}$	5·412	$8\frac{3}{8}$	2 $2\frac{1}{4}$	55·088
$2\frac{3}{4}$	$8\frac{5}{8}$	5·939	$8\frac{1}{2}$	2 $2\frac{5}{8}$	56·745
$2\frac{7}{8}$	9	6·491	$8\frac{5}{8}$	2 3	58·426
3	$9\frac{3}{8}$	7·068	$8\frac{3}{4}$	2 $3\frac{3}{8}$	60·132
$3\frac{1}{8}$	$9\frac{3}{4}$	7·669	$8\frac{7}{8}$	2 $3\frac{7}{8}$	61·862
$3\frac{1}{4}$	$10\frac{1}{4}$	8·295	9	2 $4\frac{1}{2}$	63·617
$3\frac{3}{8}$	$10\frac{5}{8}$	8·946	$9\frac{1}{8}$	2 $4\frac{5}{8}$	65·396
$3\frac{1}{2}$	11	9·621	$9\frac{1}{4}$	2 5	67·200
$3\frac{5}{8}$	$11\frac{3}{8}$	10·320	$9\frac{3}{8}$	2 $5\frac{3}{8}$	69·029
$3\frac{3}{4}$	$11\frac{3}{4}$	11·044	$9\frac{1}{2}$	2 $5\frac{3}{4}$	70·882
$3\frac{7}{8}$	$12\frac{1}{8}$	11·793	$9\frac{5}{8}$	2 $6\frac{1}{4}$	72·759
4	1 $0\frac{1}{2}$	12·566	$9\frac{3}{4}$	2 $6\frac{5}{8}$	74·662
$4\frac{1}{8}$	1 $0\frac{7}{8}$	13·364	$9\frac{7}{8}$	2 7	76·588
$4\frac{1}{4}$	1 $1\frac{3}{8}$	14·186	10	2 $7\frac{3}{8}$	78·540
$4\frac{3}{8}$	1 $1\frac{3}{4}$	15·033	$10\frac{1}{8}$	2 $7\frac{3}{4}$	80·515
$4\frac{1}{2}$	1 $2\frac{1}{8}$	15·904	$10\frac{1}{4}$	2 $8\frac{1}{8}$	82·516
$4\frac{5}{8}$	1 $2\frac{1}{2}$	16·800	$10\frac{3}{8}$	2 $8\frac{1}{2}$	84·540
$4\frac{3}{4}$	1 $2\frac{7}{8}$	17·720	$10\frac{1}{2}$	2 $8\frac{7}{8}$	86·590

CIRCUMFERENCES AND AREAS OF CIRCLES.—(*Continued.*)

Diameter in Inches.	Circumference in Feet and Inches.	Area in Square Inches	Diameter in Inches.	Circumference in Feet and Inches.	Area in Square Inches
10⅝	2 9⅜	88·664	16⅜	4 3⅜	210·597
10¾	2 9¾	90·762	16½	4 3¾	213·825
10⅞	2 10⅛	92·855	16⅝	4 4¼	217·077
11	2 10½	95·033	16¾	4 4⅝	220·353
11⅛	2 10⅞	97·205	16⅞	4 5	223·654
11¼	2 11¼	99·402	17	4 5⅜	226·980
11⅜	2 11¾	101·623	17⅛	4 5¾	230·330
11½	3 0⅛	103·869	17¼	4 6⅛	233·705
11⅝	3 0½	106·139	17⅜	4 6½	237·104
11¾	3 0⅞	108·434	17½	4 6⅞	240·528
11⅞	3 1¼	110·753	17⅝	4 7⅜	243·977
12	3 1⅝	113·097	17¾	4 7¾	247·450
12⅛	3 2	115·466	17⅞	4 8⅛	250·947
12¼	3 2½	117·859	18	4 8½	254·469
12⅜	3 2⅞	120 276	18⅛	4 8⅞	258·016
12½	3 3¼	122 718	18¼	4 9¼	261·587
12⅝	3 3⅝	125·185	18⅜	4 9¾	265·182
12¾	3 4	127·676	18½	4 10⅛	268·803
12⅞	3 4⅜	130·192	18⅝	4 10½	272·447
13	3 4¾	132·732	18¾	4 10⅞	276·117
13⅛	3 5¼	135·297	18⅞	4 11¼	279·811
13¼	3 5⅝	137·866	19	4 11⅝	283·529
13⅜	3 6	140·500	19⅛	5 0	287·272
13½	3 6⅜	143·139	19¼	5 0½	291·039
13⅝	3 6¾	145·802	19⅜	5 0⅞	294·831
13¾	3 7⅛	148·489	19½	5 1¼	298 648
13⅞	3 7½	151·201	19⅝	5 1⅝	302·489
14	3 7⅞	153·938	19¾	5 2	396·355
14⅛	3 8⅜	156·699	19⅞	5 2⅜	310·245
14¼	3 8¾	159·485	20	5 2⅞	314·160
14⅜	3 9⅛	162·295	20⅛	5 3¼	318·099
14½	3 9½	165·130	20¼	5 3⅝	322·063
14⅝	3 9⅞	167·989	20⅜	5 4	326·051
14¾	3 10¼	170·873	20½	5 4⅜	330·064
14⅞	3 10¾	173·782	20⅝	5 4¾	334·101
15	3 11⅛	176·715	20¾	5 5⅛	338 163
15⅛	3 11½	179·672	20⅞	5 5½	342·250
15¼	3 11⅞	182·654	21	5 5⅞	346·361
15⅜	4 0¼	185·661	21⅛	5 6⅜	350·497
15½	4 0⅝	188·692	21¼	5 6¾	354·657
15⅝	4 1	191·748	21⅜	5 7⅛	358·841
15¾	4 1½	194·828	21½	5 7½	363·051
15⅞	4 1⅞	197·933	21⅝	5 7⅞	367·284
16	4 2¼	201·062	21¾	5 8¼	371·543
16⅛	4 2⅝	204·216	21⅞	5 8¾	375·826
16¼	4 3	207·394	22	5 9⅛	380·133

CIRCUMFERENCES AND AREAS OF CIRCLES.—(*Continued.*)

Diameter in Inches.	Circumference in Feet and Inches.	Area in Square Inches	Diameter in Feet & Inches.	Circumference in Feet and Inches.	Area in Square Inches
22⅛	5 9½	384·465	2 7½	8 2⅞	779·313
22¼	5 9⅞	388·822	2 7¾	8 3¾	791·732
22⅜	5 10¼	393·203	2 8	8 4½	804·249
22½	5 10⅝	397·608	2 8¼	8 5⅜	816·865
22⅝	5 11	402·038	2 8½	8 6⅛	829·578
22¾	5 11½	406·493	2 8¾	8 6⅞	842·390
22⅞	5 11⅞	410·972	2 9	8 7⅝	855·300
23	6 0¼	415·476	2 9¼	8 8½	868·308
23⅛	6 0⅝	423·004	2 9½	8 9¼	881·415
23¼	6 1	424·557	2 9¾	8 10	894·619
23⅜	6 1⅜	429·135	2 10	8 10¾	907·922
23½	6 1¾	433·737	2 10¼	8 11½	921·323
23⅝	6 2¼	438·363	2 10½	9 0⅜	934·822
23¾	6 2⅝	443·014	2 10¾	9 1⅛	948·419
23⅞	6 3	447·690	2 11	9 1⅞	962·115
ft. ins.			2 11¼	9 2¾	975·908
2 0	6 3⅜	452·390	2 11½	9 3½	989·800
2 0¼	6 4⅛	461·864	2 11¾	9 4¼	1003·79
2 0½	6 4⅞	471·436	3 0	9 5	1017·87
2 0¾	6 5¾	481·106	3 0¼	9 5⅞	1032·06
2 1	6 6½	490·875	3 0½	9 6⅝	1046·35
2 1¼	6 7¼	500·741	3 0¾	9 7½	1060·73
2 1½	6 8⅛	510·706	3 1	9 8¼	1075·21
2 1¾	6 8⅞	520·769	3 1¼	9 9	1089·79
2 2	6 9⅝	530·930	3 1½	9 9⅞	1104·46
2 2¼	6 10½	541·189	3 1¾	9 10½	1119·24
2 2½	6 11¼	551·547	3 2	9 11⅜	1134·12
2 2¾	7 0	562·002	3 2¼	10 0⅛	1149·09
2 3	7 0¾	572·556	3 2½	10 0⅞	1164·16
2 3¼	7 1⅝	583·208	3 2¾	10 1¾	1179·32
2 3½	7 2⅜	593·958	3 3	10 2½	1194·59
2 3¾	7 3⅛	604·807	3 3¼	10 3¼	1209·95
2 4	7 3⅞	615·753	3 3½	10 4	1225·42
2 4¼	7 4¾	626·798	3 3¾	10 4⅞	1240·98
2 4½	7 5½	637·941	3 4	10 5⅝	1256·64
2 4¾	7 6¼	649·182	3 4¼	10 6⅜	1272·39
2 5	7 7	660·521	3 4½	10 7¼	1288·25
2 5¼	7 7⅛	671·958	3 4¾	10 8	1304·20
2 5½	7 8⅝	683·494	3 5	10 8¾	1320·25
2 5¾	7 9½	695·128	3 5¼	10 9½	1336·40
2 6	7 10¼	706·860	3 5½	10 10⅜	1352·65
2 6¼	7 11	718·690	3 5¾	10 11⅓	1369·00
2 6½	7 11¾	730·618	3 6	10 11⅞	1385·44
2 6¾	8 0⅝	742·644	3 6¼	11 0¾	1401·98
2 7	8 1⅜	754·769	3 6½	11 1½	1418.62
2 7¼	8 2⅛	766·992	3 6¾	11 2¼	1435·36

CIRCUMFERENCES AND AREAS OF CIRCLES.—*(Continued.)*

Diameter in Feet & Inches.	Circumference in Feet and Inches.	Area in Square Inches.	Diameter in Feet & Inches.	Circumference in Feet and Inches.	Area in Square Inches.
3 7	11 3	1452·20	4 6½	14 3¼	2332·83
3 7¼	11 3⅞	1469·14	4 6¾	14 4	2354·28
3 7½	11 4⅝	1486·17	4 7	14 4¾	2375·83
3 7¾	11 5⅜	1503·30	4 7¼	14 5½	2397·48
3 8	11 6¼	1530·53	4 7½	14 6⅜	2419·22
3 8¼	11 7	1537·86	4 7¾	14 7⅛	2441·07
3 8½	11 7¾	1555·28	4 8	14 7⅞	2463·01
3 8¾	11 8½	1572·81	4 8¼	14 8⅝	2485·05
3 9	11 9⅜	1590·43	4 8½	14 9½	2507·19
3 9¼	11 10⅛	1608·15	4 8¾	14 10¼	2529·42
3 9½	11 10⅞	1625·97	4 9	14 11	2551·76
3 9¾	11 11¾	1643·89	4 9¼	14 11⅞	2574·19
3 10	12 0½	1661·90	4 9½	15 0⅝	2596·72
3 10¼	12 1¼	1680·02	4 9¾	15 1⅜	2619·35
3 10½	12 2	1698·23	4 10	15 2¼	2642·08
3 10¾	12 2⅞	1716·54	4 10¼	15 2⅞	2664·91
3 11	12 3⅝	1734·94	4 10½	15 3¾	2687·83
3 11¼	12 4⅜	1753·45	4 10¾	15 4½	2710·85
3 11½	12 5¼	1772·05	4 11	15 5¼	2733·97
3 11¾	12 6	1790·76	4 11¼	15 6⅛	2757·19
4 0	12 6¾	1809·56	4 11½	15 6⅞	2780·51
4 0¼	12 7½	1828·46	4 11¾	15 7¾	2803·92
4 0½	12 8⅜	1847·45	5 0	15 8½	2827·44
4 0¾	12 9⅛	1866·55	5 0¼	15 9¼	2851·05
4 1	12 9⅞	1885·74	5 0½	15 10	2874·76
4 1¼	12 10¾	1905·03	5 0¾	15 10¾	2898·56
4 1½	12 11½	1924·42	5 1	16 11⅝	2922·47
4 1¾	13 0¼	1943·91	5 1¼	16 0⅜	2946·47
4 2	13 1	1963·50	5 1½	16 1¼	2970·57
4 2¼	13 1⅞	1983·18	5 1¾	16 1⅞	2994·77
4 2½	13 2⅝	2002·96	5 2	16 2¾	3019·07
4 2¾	13 3⅜	2022·84	5 2¼	16 3½	3043·47
4 3	13 4¼	2042·82	5 2½	16 4¼	3067·96
4 3¼	13 5	2062·90	5 2¾	16 5⅛	3092·56
4 3½	13 5¾	2083·07	5 3	16 5⅞	3117·25
4 3¾	13 6½	2103·35	5 3¼	16 6¼	3142·04
4 4	13 7⅜	2123·72	5 3½	16 7½	3166·92
4 4¼	13 8⅛	2144·19	5 3¾	16 8¼	3191·91
4 4½	13 8⅞	2164·75	5 4	16 9	3216·99
4 4¾	13 9¾	2185·42	5 4¼	16 9¾	3242·17
4 5	13 10½	2206·18	5 4½	16 10⅝	3267·46
4 5¼	13 11¼	2227·05	5 4¾	16 11⅜	3292·83
4 5½	14 0	2248·01	5 5	17 0⅛	3318·31
4 5¾	14 0⅞	2269·06	5 5¼	17 0⅞	3343·88
4 6	14 1⅝	2290·22	5 5½	17 1¾	3369·56
4 6¼	14 2⅜	2311·48	5 5¾	17 2½	3395·33

CIRCUMFERENCES AND AREAS OF CIRCLES.—(*Continued.*)

Diameter in Feet & Inches.	Circumference in Feet and Inches.	Area in Square Inches.	Diameter in Feet & Inches.	Circumference in Feet and Inches.	Area in Square Inches.
5 6	17 3⅜	3421·20	6 5½	20 3½	4717·30
5 6¼	17 4⅛	3447·16	6 5¾	20 4¼	4747·79
5 6½	17 4⅞	3473·23	6 6	20 5	4778·37
5 6¾	17 5⅝	3499·39	6 6¼	20 5¾	4809·05
5 7	17 6½	3525·26	6 6½	20 6½	4839·83
5 7¼	17 7¼	3552·01	6 6¾	20 7⅛	4870·70
5 7½	17 8	3578·47	6 7	20 8⅛	4901·68
5 7¾	17 8¾	3605·03	6 7¼	20 8⅞	4932·75
5 8	17 9⅝	3631·68	6 7½	20 9¾	4963·92
5 8¼	17 10⅜	3658·44	6 7¾	20 10½	4995·19
5 8½	17 11⅛	3685·29	6 8	20 11¼	5026·26
5 8¾	17 11⅞	3712·24	6 8¼	21 0⅛	5058·02
5 9	18 0¾	3739·28	6 8½	21 0⅞	5089·58
5 9¼	18 1½	3766·43	6 8¾	21 1⅝	5121·24
5 9½	18 2¼	3793·67	6 9	21 2⅜	5153·00
5 9¾	18 3⅛	3821·02	6 9¼	21 3¼	5184·86
5 10	18 3⅞	3848·46	6 9½	21 4	5216·82
5 10¼	18 4⅜	3875·99	6 9¾	21 4¾	5248·87
5 10½	18 5½	3903·63	6 10	21 5½	5281·02
5 10¾	18 6¼	3931·36	6 10¼	21 6⅜	5313·27
5 11	18 7	3959·20	6 10½	21 7⅛	5345·62
5 11¼	18 7¾	3987·13	6 10¾	21 7⅞	5378·07
5 11½	18 8⅝	4015·16	6 11	21 8¾	5410·62
5 11¾	18 9⅜	4043·28	6 11¼	21 9½	5443·26
6 0	18 10⅛	4071·51	6 11½	21 10¼	5476·00
6 0¼	18 10⅞	4099·83	6 11¾	21 11	5508·84
6 0½	18 11¾	4128·25			Square Feet.
6 0¾	19 0½	4156·77	7 0	21 11⅞	38·4846
6 1	19 1¼	4185·39	7 1	22 3	39·4060
6 1¼	19 2⅛	4214·11	7 2	22 6⅛	40·3388
6 1½	19 2⅞	4242·92	7 3	22 9¼	41·2825
6 1¾	19 3⅝	4271·83	7 4	23 0⅜	42·2367
6 2	19 4½	4300·85	7 5	23 2⅛	43·2022
6 2¼	19 5¼	4329·95	7 6	23 6¾	44·1787
6 2½	19 6	4359·16	7 7	23 11	45·1656
6 2¾	19 6¾	4388·47	7 8	24 1⅛	46·1638
6 3	19 7⅝	4417·87	7 9	24 4⅛	47·1730
6 3¼	19 8⅜	4447·37	7 10	24 7¼	48·1926
6 3½	19 9⅛	4476·97	7 11	24 10⅜	49·2236
6 3¾	19 9⅞	4506·67	8 0	25 1½	50·2656
6 4	19 10¾	4536·47	8 1	25 4⅝	51·6178
6 4¼	19 11½	4566·36	8 2	25 7⅞	52·3816
6 4½	20 0¼	4596·35	8 3	25 11	53·4562
6 4¾	20 1⅛	4626·44	8 4	26 2⅛	54·5412
6 5	20 1⅞	4656·63	8 5	26 5¼	55·6377
6 5¼	20 2⅝	4686·92	8 6	26 8¾	56·7451

CIRCUMFERENCES AND AREAS OF CIRCLES.—*(Continued.)*

Diameter in Feet & Inches.		Circumference in Feet and Inches.		Area in Square Feet.	Diameter in Feet & Inches.		Circumference in Feet and Inches.		Area in Square Feet.
8	7	26	11½	57·8628	12	5	39	0	121·0876
8	8	27	2¾	58·9920	12	6	39	3¼	122·7187
8	9	27	5¾	60·1321	12	7	39	6⅜	124·3598
8	10	27	9	61·2826	12	8	39	9½	126·0127
8	11	28	0⅛	62·4445	12	9	40	0⅝	127·6765
9	0	28	3¼	63·6174	12	10	40	3¾	129·3504
9	1	28	6⅜	64·8006	12	11	40	6⅞	131·0360
9	2	28	9½	65·9951	13	0	40	10	132·7326
9	3	29	0⅝	67·2007	13	1	41	1⅛	134·4391
9	4	29	3¾	68·4166	13	2	41	4⅜	136·1574
9	5	29	7	69·6440	13	3	41	7½	137·8867
9	6	29	10⅛	70·8823	13	4	41	10⅝	139·6260
9	7	30	1¼	72·1309	13	5	42	1¾	141·3771
9	8	30	4⅜	73·3910	13	6	42	4⅞	143·1391
9	9	30	7½	74·6620	13	7	42	8	144·9111
9	10	30	11⅝	75·9433	13	8	42	11⅛	146·6949
9	11	30	1¾	77·2362	13	9	43	2¼	148·4896
10	0	31	5	78·5400	13	10	43	5½	150·2943
10	1	31	8⅛	79·8540	13	11	43	8⅝	152·1109
10	2	31	11¼	81·1795	14	0	43	11¾	153·9484
10	3	32	2⅜	82·5190	14	1	44	2⅞	155·7758
10	4	32	5½	83·8627	14	2	44	6	157·6250
10	5	32	8⅝	85·2211	14	3	44	9⅛	159·4852
10	6	32	11¾	86·5903	14	4	45	0¼	161·3553
10	7	33	2⅞	87·9697	14	5	45	3½	163·2373
10	8	33	6⅛	89·3668	14	6	45	6⅝	165·1303
10	9	33	9¼	90·7627	14	7	45	9¾	167·0331
10	10	34	0⅜	92·1749	14	8	46	0⅞	168·9479
10	11	34	3½	93·5986	14	9	46	4	170·8735
11	0	34	6⅝	95·0334	14	10	46	7⅛	172·8091
11	1	34	9¾	96·4783	14	11	46	11¼	174·7565
11	2	35	0⅞	97·9347	15	0	47	1½	176·7150
11	3	35	4⅛	99·4029	15	1	47	4⅝	178·6832
11	4	35	7¼	100·8797	15	2	47	7¾	180·6634
11	5	35	10⅝	102·3689	15	3	47	10⅞	182·6545
11	6	36	1½	103·8001	15	4	48	2½	184·6555
11	7	36	4½	105·3794	15	5	48	5⅛	186·6684
11	8	36	7¾	106·9013	15	6	48	8¼	188·6923
11	9	36	10⅞	108·4342	15	7	48	11⅜	190·7260
11	10	37	2¾	109·9772	15	8	49	2⅝	192·7716
11	11	37	5¼	111·5319	15	9	49	5¾	194·8282
12	0	37	8⅜	113·0976	15	10	49	8⅞	196·8946
12	1	37	11½	114·6732	15	11	50	0	198·9730
12	2	38	2⅝	116·2607	16	0	50	3⅛	201·0624
12	3	38	5¾	117·8590	16	1	50	6¼	203·1615
12	4	38	8⅞	119·4674	16	2	50	9⅝	205·2726

CIRCUMFERENCES AND AREAS OF CIRCLES.—(*Continued.*)

Diameter in Feet & Inches.	Circumference in Feet and Inches.	Area in Square Feet.	Diameter in Feet & Inches.	Circumference in Feet and Inches.	Area in Square Feet.
16 3	51 0½	207·3946	17 8	55 6	245·1316
16 4	51 3¼	209·5264	17 9	55 9⅛	247·4500
16 5	51 6½	211·6703	17 10	56 0¼	249·7781
16 6	51 10	213·8251	17 11	56 3½	252·1184
16 7	52 1⅛	215·9896	18 0	56 6½	254·4696
16 8	52 4¼	218·1662	18 1	56 9⅝	256·8303
16 9	52 7⅛	220·3537	18 2	57 0⅞	259·2033
16 10	52 10½	222·5510	18 3	57 4	261·5872
16 11	53 1⅝	224·7603	18 4	57 7⅛	263·9807
17 0	53 4⅞	226·9806	18 5	57 10¼	266·3864
17 1	53 8	229·2105	18 6	58 1⅜	268·8031
17 2	53 11⅛	231·4625	18 7	58 4½	271·2293
17 3	54 2⅛	233·7055	18 8	58 7⅝	273·6678
17 4	54 5⅜	235·9682	18 9	58 10¾	276·1171
17 5	54 8½	238·2430	18 10	59 2	278·5761
17 6	54 11⅝	240·5287	18 11	59 0⅛	291·0472
17 7	55 2⅞	242·8241			

WEIGHT OF A SQUARE FOOT OF WROUGHT IRON FROM 1/16 TO 2 INCHES THICK.

THICK.	WROUGHT IRON, HARD ROLL.	THICK.	WROUGHT IRON, HARD ROLL.
1/16	2·517	13/16	32·729
⅛	5·035	⅞	35·247
3/16	7·552	15/16	37·764
¼	10·070	1	40·282
5/16	12·588	1⅛	45·317
⅜	15·106	1¼	50·352
7/16	17·623	1⅜	55·387
½	20·141	1½	60·422
9/16	22·659	1⅝	65·458
⅝	25·176	1¾	70·493
11/16	27·694	1⅞	75·528
¾	30·211	2	80·563

WEIGHT OF SQUARE ROLLED IRON, FROM ¼ INCH TO 12 INCHES, AND 1 FOOT IN LENGTH.

SIZE IN INCHES.	WEIGHT IN POUNDS.	SIZE IN INCHES.	WEIGHT IN POUNDS.
¼	0·2	4¾	76·3
⅜	0·5	4⅞	80·3
½	0·8	5	84·5
⅝	1.3	5⅛	88·8
¾	1·9	5¼	93·2
⅞	2·6	5⅜	97·7
1	3·4	5½	102·2
1⅛	4·3	5⅝	107·0
1¼	5·3	5¾	111·8
1⅜	6·4	5⅞	116·7
1½	7·6	6	121·7
1⅝	8·9	6¼	132·0
1¾	10·4	6½	142·8
1⅞	11·9	6¾	154·0
2	13·5	7	165·6
2⅛	15·3	7¼	177·7
2¼	17·1	7½	190·1
2⅜	19·1	7¾	203·0
2½	21·1	8	216·3
2⅝	23·3	8¼	230·1
2¾	25·6	8½	244·2
2⅞	27·9	8¾	258·8
3	30·4	9	273·8
3⅛	33·0	9¼	289·2
3¼	35·7	9½	305·1
3⅜	38·5	9¾	321·3
3½	41·4	10	337·9
3⅝	44·4	10¼	355·1
3¾	47·5	10½	372·7
3⅞	50·8	10¾	390·6
4	54·1	11	409·0
4⅛	57·5	11¼	427·8
4¼	61·1	11½	447·0
4⅜	64·7	11¾	466·7
4½	68·4	12	486·7
4⅝	72·3		

WEIGHT OF FLAT ROLLED IRON FROM ⅛ + ½-INCH TO 1 + 6-INCH.

Thick.	Width.	Weight in lbs.	Thick.	Width.	Weight in lbs.	Thick.	Width.	Weight in lbs.
⅛	½	0·211	⅜	4	5·1	⅝	3¼	6·9
⅛	⅝	0·264	⅜	4¼	5·4	⅝	3½	7·4
⅛	¾	0·316	⅜	4½	5·7	⅝	3¾	7·9
⅛	⅞	0·369	⅜	4¾	6·0	⅝	4	8·4
⅛	1	0·422	⅜	5	6·3	⅝	4¼	9·0
⅛	1⅛	0·475	⅜	5¼	6·7	⅝	4½	9·5
¼	1	0·8	⅜	5½	7·0	⅝	4¾	10·0
¼	1¼	1·1	⅜	5¾	7·3	⅝	5	10·6
¼	1½	1·3	⅜	6	7·6	⅝	5¼	11·1
¼	1¾	1·5	½	1	1·7	⅝	5½	11·6
¼	2	1·7	½	1¼	2·1	⅝	5¾	12·1
¼	2¼	1·9	½	1½	2·5	⅝	6	12·7
¼	2½	2·1	½	1¾	3·0	¾	1	2·5
¼	2¾	2·3	½	2	3·4	¾	1¼	3·2
¼	3	2·5	½	2¼	3·8	¾	1½	3·8
¼	3¼	2·7	½	2½	4·2	¾	1¾	4·4
¼	3½	3·0	½	2¾	4·6	¾	2	5·1
¼	3¾	3·2	½	3	5·1	¾	2¼	5·7
¼	4	3·4	½	3¼	5·5	¾	2½	6·3
¼	4¼	3·6	½	3½	5·9	¾	2¾	7·0
¼	4½	3·8	½	3¾	6·3	¾	3	7·6
¼	4¾	4·0	½	4	6·8	¾	3¼	8·2
¼	5	4·2	½	4¼	7·2	¾	3½	8·9
¼	5¼	4·4	½	4½	7·6	¾	3¾	9·5
¼	5½	4·6	½	4¾	8·0	¾	4	10·1
¼	5¾	4·9	½	5	8·4	¾	4¼	10·8
¼	6	5·1	½	5¼	8·9	¾	4½	11·4
⅜	1	1·3	½	5½	9·3	¾	4¾	12·0
⅜	1¼	1·6	½	5¾	9·7	¾	5	12·7
⅜	1½	1·9	½	6	10·1	¾	5¼	13·3
⅜	1¾	2·2	⅝	1	2·1	¾	5½	13·9
⅜	2	2·5	⅝	1¼	2·6	¾	5¾	14·6
⅜	2¼	2·9	⅝	1½	3·2	¾	6	15·2
⅜	2½	3·2	⅝	1¾	3·7	1	1½	5·1
⅜	2¾	3·5	⅝	2	4·2	1	2	6·8
⅜	3	3·8	⅝	2¼	4·8	1	3	10·1
⅜	3¼	4·1	⅝	2½	5·8	1	4	13·5
⅜	3½	4·4	⅝	2¾	5·8	1	5	16·9
⅜	3¾	4·8	⅝	3	6·3	1	6	20·3

WEIGHT OF ROUND ROLLED IRON FROM ¼-INCH TO 12 INCHES IN DIAMETER, AND 1 FOOT IN LENGTH.

Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.
¼	0·2	4¾	60·0
⅜	0·4	4⅞	63·1
½	0·7	5	66·8
⅝	1·0	5⅛	69·7
¾	1·5	5¼	73·2
⅞	2·0	5⅜	76·7
1	2·7	5½	80·3
1⅛	3·4	5⅝	84·0
1¼	4·2	5¾	87·8
1⅜	5·0	5⅞	91·6
1½	6·0	6	95·6
1⅝	7·0	6¼	103·7
1¾	8·1	6½	112·2
1⅞	9·3	6¾	121·0
2	10·6	7	130·0
2⅛	12·0	7¼	139·5
2¼	13·5	7½	149·3
2⅜	15·0	7¾	159·5
2½	16·7	8	169·9
2⅝	18·8	8¼	180·7
2¾	20·1	8½	191·8
2⅞	21·9	8¾	203·3
3	23·9	9	215·0
3⅛	25·9	9¼	227·2
3¼	28·0	9½	239·6
3⅜	30·2	9¾	252·4
3½	32·5	10	266·3
3⅝	34·9	10¼	278·9
3¾	37·3	10½	292·7
3⅞	39·9	10¾	306·8
4	42·5	11	321·2
4⅛	45·2	11¼	336·0
4¼	48·0	11½	351·1
4⅜	50·8	11¾	366·5
4½	53·8	12	382·2
4⅝	56·8		

LOCOMOTIVE BOILERS.

The following is a standard list of prices which was paid in the Boiler department of Messrs. Sharp, Stewart & Co., Manchester :—

STANDARD BOILER—BODY, 8 PLATES.

Marking, Bending, Setting, Punching, Shearing, and Bolting together 16 Welts; Bending, Marking, Punching, and Plating	£4	13	0
Rhymering and Riveting	1	7	6
A. I. Ring, Setting out and Punching	0	4	6
Chipping Welts and Fitting them on	0	4	0
Riveting Welts on	0	16	0
Odd Rivets and Calking Boiler	1	11	6
12 T Irons for Stays, Marking and Punching ..	0	3	0
Fitting on and Riveting	0	18	0
Setting out Foundation Ring	0	2	2
Side and Roof Plates, Shearing	0	1	6
Side Plates, Thinning and Marking	0	4	6
" Punching, Shearing Bending, and Setting	0	8	0
Marking Roof Plates, Punching, and Shearing ...	0	4	0
Bending and Setting Roof Plates	0	2	0
Front and Back Plates, Marking, Punching, and Shearing	0	5	0
Front and Back Plates, Setting and Marking for Punching and Shearing, Drilling and Planing	0	13	0
Front and Back Plates, Punching and Shearing bottom	0	2	6
Front and Back Plates, Thinning and Fitting to Ring	0	5	0
Marking and Punching Flanges	0	9	6
" for Junction Ring...	0	6	10
Fire Box, Plating up...	0	6	6
	£13	8	0

Brought forward				£13	8	0
Flat Sides, Plating up	£0	5	0	1	11	0
Corners, large radius	1	0	0			
Hand Riveting	0	6	0			
Junction Ring, Flanging				0	10	0
Two Roof Bars, Marking and Punching				1	6	0
Valve Seat, Marking, Punching, and Setting				0	7	0
Riveting Fire Box by machine				0	12	0
Jointing Boiler (9/6) and Marking Tube Plate (3/-)				0	12	6
Dome Top, Plating				0	10	0
Riveting Dome Top, 85 rivets				0	13	0
Dome Seat, Plating 13/-, Riveting 12/-				0	5	0
Tube Plate, Marking, Punching, Setting out for Drilling				0	7	0
Jointing and Rhymering				0	2	0
188 Rivets, Riveting and Calking				1	18	0
Fire Box, Odd Rivets and Calking				0	12	6
52 Rivets in Roof Bars				0	15	0
Tube Plate, Riveting and Calking, 104 Rivets				1	12	6
4 Gusset Stays, Plating				0	10	0
				£25	11	6

REMARKS.

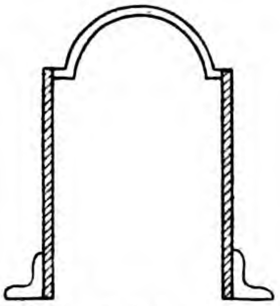
The Standard Boiler (607), is 13 feet 6 inches long and 3 feet 10 inches diameter inside the small end, lap-jointed round the circle, with butt joints and welts on the longitudinal seams; 4 rings of plates with 8 welts outside and 8 welts inside, outside welts 5/-, inside welts 1/8 extra; the welts are double riveted "zig-zag," the junction ring on fire-box and boiler body ring to smoke-box are also "zig-zag;" junction ring, 188 rivets, and calking, 4/3 per score; tube plates, 104 point rivets, 6/3 per score; the fire-box has hollow and round sides, the four corners on the foundation-ring are of larger radius than the body of the flange plate, gradually diminishing from the bottom upwards; there was an allowance of £1 per box, or 5/- per corner extra for them, and 2/6 for sides for fitting junction to the flat sides of box; 4 large corners at 2/6, 10/- per box. There are about 48 rivets, hand-riveted, in these corners, for which 6/- per box was paid. Top dome plated, crown plate flanged, and an angle-iron ring on bottom edge; dome seat flattened; A. iron ring top and bottom. Valve seat plate welded and flanged; smoke box tube plate, common shape. In comparing drawings for estimates an allowance was made for boiler body, 2/- per inch above or below 3 feet 10 inches inside, and 6d. per inch in length above or below 13 feet 6 inches; outside welts, double-riveted, 5/- each extra; do., do., single, 3/-; inside welts, 1/8; do., do., do., 1/2; inside small covering plates, 4d. This allowance includes riveting, calking, plating, riveting A. iron rings, and all complete ready for jointing.

For fire-box an allowance of 2/- per foot for plating and riveting by machine and calking.

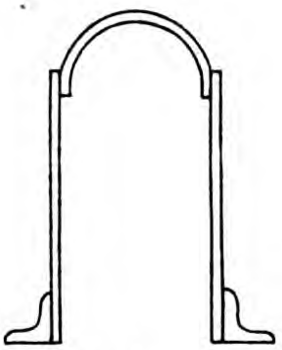
Roof stay bars, 2/- per foot, longer or shorter. The standard roof stay bars are T iron, 4 feet 6 inches long, and contain 52 rivets over all. For riveting by hand and by machine, ordinary work, cup rivets 2/4, point rivets, 3/- per score extra. When the tube plate A. I. ring is heated and flanged back on the edge to fit the tube plate, 5/- per boiler extra.

Copper fire-box, plain, plating included, bearing and hand-drilling corners, 1/6 per foot.

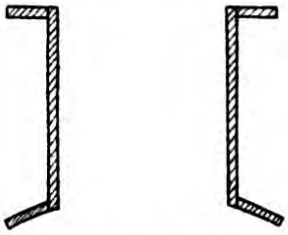
Fire door plate tank to fit the ring, 2/6 each extra. Plates sunk to fit the foundation ring, 1/6 per plate extra. If sides or roof plates are flanged over to fit the flange plates, 2d. per foot extra. Iron fire-boxes and copper, 2/- per foot plating; riveting do., 4/6 per score. Copper boxes, riveting 3/2¼ per score. Boiler body rings, when bent all in a plate, 1/9 extra. Plate junction rings, or throat plates, are considered equal to a common A. I. junction ring, flanging included, in 4-body plates and a crown plate.



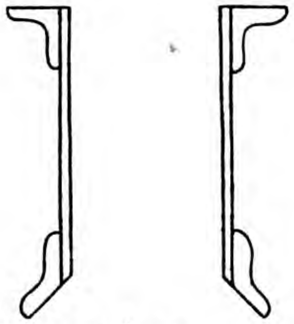
Plating 22/- Rivetting 15/-



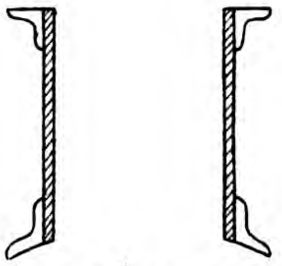
Plating 10/- Rivetting 13/-



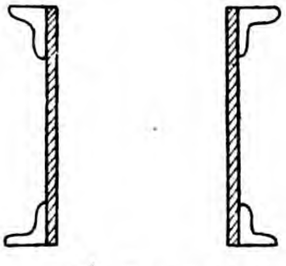
Plating Solid 12/6



Plating 14/6 Rivetting 13/-



Plating 13/- Rivetting 12/-



Plating 8/6 Rivetting 11/6

Valve Seat Solid 7/-

PRICES OF CUTTING AND SETTING ANGLE IRON.

3 × 3, under 8 feet long	1d. each.
Over 3 and under 1 foot 7 inches long	4d. „
Elbows or bent A. I. cutting	1d. „
3 × 3, 8 feet long or over	8d. „
Over 3 and 1 foot 7 inches long or over	8d. „
Expansion A. I. cutting	1/- „

CUTTING AND PUNCHING BALANCE PLATES AND RIVETING THE SAME IN WHEELS :—

	Cutting Plates.	Riveting Wheels.
4 rivets in each wheel	7½d. each...	3/- per pair.
6 „ „	7½d. „ ...	4/- „
9 „ „	9d. „ ...	5/- „
12 „ „	9d. „ ...	5/10 „
15 „ „	10d. „ ...	6/9 „
18 „ „	1/- „ ...	7/6 „

Riveting horn blocks in framing, 2½d. per rivet.

Sheet iron templates for framing fire-box, smoke-box, tube plate, tube hole plate, motion plate, &c.

Piercing-up, straightening, and punching, all complete, 3d. per square foot; the measurement to be taken from the Template Shop; punching and setting small templates to be paid for by valuation.

Jobbing and finishing engines, 15/- per engine, large or small, for main plates, flame plates, friction and strengthening plates, platform welts, draw plates, flanges, firehole doors, copper washers, &c.

Copper flange plates, setting and cutting to length, if ready flanged, 6/- per plate; if marked out and punched out for flanging 7/6 per plate; if bent, 9/- per plate. Side or roof plates, 1/. Iron tube plates, marking, punching, and shearing for flanging, 6/- each. Fire-box flange plates, marking out, punching and shearing, setting when flanged, marking for planing, and cutting to length, 13/- each. Fire-box sides, or roof plates, or boiler body plates, rolling and levelling for planing 2/- each. Number of Rivets for Standard Boiler 716, eight times 58 and three times 84. In comparing drawings it is always considered a round tube plate, if riveted on the end of the boiler, is equal in all respects to the common tube plate. A round tube plate, if fitting inside the boiler, is nearly equal in setting out for shearing, drilling, &c. A plater fitting it into its place is equal to marking a common tube plate when jointing a boiler. Riveting and calking is equal to plating and riveting the A. I. ring on the end of the boiler, but there is no riveting of point rivets round the tube plate, the price of which in standard is £1 12s. 6d.; therefore a boiler with a round tube plate inside, the price of which is £1 12s. 6d. less than a common one.

Copper stays, 2 ends, 3d. each; iron stays, 2 ends, 5d. Valve seat and roof bar rivets, 2½d. each. Expansion A. irons rivets, 3½d. Putting in box and chipping bars, 10/. Riveting mouth-piece and calking, per rivet, 5½d. Stays to copper tube plate, 3½d. Dome seat and calking per rivet, 3½d. Hand-rail, brackets, clack boxes, and rubber plates, per rivet, 4d. Regulator pipe carrier, per rivet, 6d. Testing with water, 20/. Testing with steam, 10/.

Rivets in motion bracket, 4½d. Turning boiler, 8/. Riveting foundation ring and calking do., per rivet, 5d. each. Per rivet in copper box and calking, $2\frac{1}{24}$d. Front and back T irons, per rivet, 3¼d. Gusset stay rivets, 3¼d. Sundries, and preparing to riveting regulator handle, carrying and getting scaffold—allow for same 11/6. Rivets in steam blower bracket, whistle bracket, tank carrier, and brake screw bracket, 4d. each.

Riveting all sizes of rivets on platform, smoke-box, and cabs, 2/7½ per score. Setting tube plate, 10/. Setting smoke-box door, 10/. Hand rivets in boiler and fire-box, 3/3 per score. Odd rivets and calking boiler, 31/6 per boiler. Angle iron junction ring, calking included, 4/3 per score. Riveting tube plate, smoke-box end, calking included, 6/3 per score.

Tender rivets, all sorts, 1/7 per score. Riveting boiler by machine, 11d. per score.

PRICES OF ANGLE IRON WORK.

1	Single Elbow,	1¼ × 1¼ × 3/16,	5d.	... 1	Single Elbow,	2 × 2 × ¼...	9d.
1	" "	1½ × 1½ × ¼	7d.	... 1	" "	2¼ × 2¼ × ¼	11d.
1	" "	1¾ × 1¾ × ¼		... 1	" "	2½ × 2½ × ⅜	
1	" "	2¾ × 2¾ × ½	1/4	... 1	" "	3½ × 3½ × ¾	2/6
1	" "	3 × 3 × ⅜		... 1	" "	4 × 4 × ¾	
1	Double "	1¼ × 1¼ × 3/16,	1/2	... 1	Double "	2 × 2 × ¼...	1/10
1	" "	1½ × 1½ × ¼	1/4	... 1	" "	2¼ × 2¼ × ¼	2/2
1	" "	1¾ × 1¾ × ¼		... 1	" "	2½ × 2½ × ⅜	
1	" "	2¾ × 2¾ × ½	3/2	... 1	" "	3½ × 3½ × ¾	8/-
1	' "	3 × 3 × ⅝		... 1	" "	4 × 4 × ¾	

1 Angle-iron ring for boiler 3½ up to 4 × ⅝, complete, 7/2. 1 Dome ring, 3¼ × 3¼ × ⅝, 6/. 1 Saddle ring, 3¼ × 3¼ × ⅝, 4/6. Flanging tube pate, 11d. per foot, as per block. Segments, 1/1 per foot. Opening angle-iron to suit incline, 1¼d., 2½d., to 3d. per foot. Smithing and finishing dome, 63/.

Dome seating	... ...	from 28/- to 55/-
Square A. I. frames,	1¼ to 2	3/2
" "	2½ × 2½	6/9
" "	3 × 3	16/3
" "	4 × 4	25/-
Angle-iron rings,	2½ × 2½ × ⅜	1
" "	2¼ × 2¼ × 5/16	1/-
" "	2 × 2 × ¼	1/-
" "	1¾ × 1¾ × ¼	1/-
' . "	1½ × 1½ × ¼	1/-
" "	1¼ × 1¼ × ¼	1/-

Inside and outside rings all one price.

Saddle tank, angle iron,	large size	26/1
, "	small size	22/6

Double elbows, from 12 ft. to 20 ft. 3 ins. (A. I.) $\times \frac{5}{8}$	8/1
" " 8 ft. to 12 ft. "	6/-
Any width below the above	3/2
Single elbows, from 12 ft. to 20 ft., $3 \times 3 \times \frac{5}{8}$	6/-
" " 8 ft. to 12 ft., $3 \times 3 \times \frac{5}{8}$	3/-
Any length below the above	1/4
Angle iron frames, 4 ft. long, 2 ft. wide, $3 \times 3 \times \frac{5}{8}$	16/-
" " 2 ft. " 1 ft. " "	6/9

All inside and outside elbows one price.

$2\frac{3}{4} \times 2\frac{3}{4} \times \frac{1}{2}$	6/9
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	6/9
Double elbows, from 12 ft. to 20 ft.	4/6
" " 8 ft. to 12 ft.	3/6
Any length below the above	2/2
Single elbows, from 12 ft. to 20 ft.	2/6
" " 8 ft. to 12 ft.	1/6
Any length below the above	11d.
Double elbows, $2 \times 2 \times \frac{1}{4}$	1/10
Single elbows, $1\frac{3}{4} \times 1\frac{3}{4} \times \frac{1}{4}$	9d.
Double elbows	1/6
Single elbows, $1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{4}$	7d.
Double elbows	1/1
Single elbows	5d.

SECTION II.

IRON SHIPBUILDING.

The extended and increasing use of iron ships at the present day, after the lapse of about forty years since they were first fairly introduced, renders their construction a subject of importance to those who are engaged in it; for the application of iron in place of wood to the structure of ships has necessitated a more careful use of the material employed, and a more correct and perfect application of the mechanical principles that are involved in the construction. It is not intended in the present article to describe novelties of construction in iron ships so much as to give practical information.

The main points of superiority of iron ships over those built of wood consist in the superior strength, greater durability, and less cost of iron ships, together with their larger carrying capability, greater facility of construction, and the more certain supply of the material.

The greater strength of iron ships is shown in daily practice in numerous ways; and it is also shown by the fact that in many modern wood ships it has been found desirable to introduce the use of iron for bulkheads, beams, and stringers, and even for the frame work itself of the whole structure. But this arrangement it is considered falls very far short in point of strength of a vessel built entirely of iron.

The greater comparative durability of iron for the construction of ships arises mainly from its freedom from the decay to which wood is always liable in consequence of its being unavoidably subject to constant and extreme variations of temperature and moisture. Another important source of this greater durability is to be found in the firm and substantial union of the several parts of an iron ship by means of riveting, which effectually prevents that *working* under heavy strains to which all wood ships are more or less liable.

The larger carrying capability of the iron ship arises first from the reduced weight of the structure, and, secondly from the increased internal capacity with the same external dimensions and model as the wood ship. This is shown by the following figures of comparison of a 1200-ton ship of the two constructions. First, as to weight. The wood ship with rigging and all outfit weighs say 18 cwt. a ton measure, equal to 1080 tons for the whole ship. The iron ship completed in a similar way weighs only say 15 cwt. a ton measure, which would be equal to 900 tons for the whole ship. Hence the 1200-ton iron ship will carry at the same draught 180 tons additional dead weight of cargo; and this will be equal to 11 per cent. addition upon the whole weight of 1600 tons which is actually carried by a nominal 1200-ton wood ship; or if no greater weight be carried, the iron vessel will float at 13 inches draught of water. Secondly, as to capacity. The wood ship has an internal capacity of 93,343 cubic feet, or, at 100 feet a ton, 933 tons. The iron ship, because of the reduced thickness of the sides and bottom of the hull, has a capacity of 1108 tons. Hence, in regard to capacity, the gain of the iron ship is 175 tons, or about 19 per cent. over the wood ship; and there will constantly be space enough to contain the increased weight of 11 per cent. which the iron ship is capable of carrying by reason of its lighter hull.

The mode of riveting adopted in large first-class vessels is principally what is termed chain-riveting, both in the longitudinal and vertical joints; but in addition the principal stringer-plates in the upper parts of the vessel, and the sheer-strakes in the midships, have further rows of rivets with increased lap of the joint-plates, making the joints in these cases treble or quadruple riveted.

The joints for the plating have now become more perfect than formerly, by the use of the planing machine. The edges of the plates for the butt-joints are planed perfectly straight and smooth, and they are thus brought into accurate contact with each other, so as to form a true and close joint, which could not previously be attained by shearing and the too common practice of hammering up the edges of the plates. All necessity for undue calking and the use of lining strips is thus avoided, and the best strength of the material is imparted to the ship. The quality of iron employed for shipbuilding should in all cases be equal to a tensile strength of at least 20 tons the square inch, and a direct and habitual system of testing should be constantly carried out.

The following are a few practical instructions in iron shipbuilding :—

KEELS.

In boring keel-bars be particular to have the top row of rivet-holes marked no lower down than is necessary to make a good and close fit of the garboard strake at the top row of holes, and on no account weaken the keel-bar by having the lower row of holes bored too low down ; at the same time care must be taken to have a distance equal to the diameter of rivets between the lower edge of upper row and upper edge of bottom row ; a distance of two diameters between the centre lines of the top and bottom rows. In marking off the holes, attention should be paid to having them properly divided ; that is to say, having the upper rivet exactly between the two lower rivets. Make the length of scarfs of keel-bars at least ten times the thickness of the keel-bar. Lloyd's rules give only eight times, but this is too little to make a substantial connection.

Before commencing to drill the scarfs, have them drawn perfectly close, and see that the ends are brought together, and are a good fit.

It is not necessary to drill more than three holes in scarfs for stitching, and these should be on the top part, so as not to weaken the keel-bar more than necessary.

The upper side of scarf should be calked before the frames are laid across keel, and the under side after the keel-plates are riveted.

The butts of the garboard strake must be spaced so as to be well clear of the butts of keel-bar; say at least 30 inches when practicable, and with care this distance can generally be given.

Have the position of all frames marked on the keel with a centre punch before any of the frames are laid across; this will save a deal of unnecessary trouble.

See that the keel-bars are properly shored, straightened on top edge, and got quite fair previous to laying any frames over them. Attention must also be paid to fairing the keel fore-and-aft by a line, after the frames are up in place, before commencing to fit any of the garboard strake on.

It is important to keep the keel a reasonable height from the ground, so as to allow room for the workmen to get under the vessel's bottom without being too much confined; otherwise they cannot make good work of the riveting and calking. In settling this point, bear in mind that if the vessel has a flat floor the blocks must be laid higher.

Let the keel-blocks be spaced about 7 feet 6 inches apart, and have a double block between, say every second and third block alternately. This will allow for shifting any blocks that may be necessary to get at the work without fear of the vessel settling down. Have the three or four last blocks laid on fore-and-aft logs, as the vessel will be certain to sink at after-end, if anywhere.

It is well to have the keel riveted as soon as possible, to prevent any dirt or rubbish getting down between the keel and garboard strake.

FLAT-PLATE KEELS.

If for a vessel building to class at Lloyd's, the breadth and thickness must be as follows :—In vessels of 500 tons and under, 2 feet wide; from 500 to 1000 tons, 2 feet 6 inches wide; 1000 tons and upwards, 3 feet wide. The thickness of plates in all cases to be not less than one-and-a-half times the thickness of the garboard strake.

It is desirable in flat-plate keels that the butts of the garboard strake should be clear of the butts of keel-plates at least two spaces of frames on both the port and starboard sides; and for this reason the keel-plates should be made in such lengths as will suit this; also see that the butts of the keel-plates are fair between two frames, as this is necessary to facilitate the putting on of the butt-straps.

In all cases it is recommended to treble-rivet the butts of keel-plate, making the butt-straps as wide as can be got in between the flange of the frame angle-irons and heel-pieces on next frame.

STERN-POSTS AND STERN-FRAMES.

In a screw steamer, care must be taken in boring any holes about the boss that may be required, and this should be done previous to putting the frame up in place. Mark off the lead of these holes so that they may be bored in the proper direction, and thereby have a proper divide on the inside of the boss.

Particular attention should be paid to taking out any twist that may be in the stern-frame when it comes from the forge, and be careful to see that the bosses on both outer and inner post lead fair fore-and-aft.

In the upper portion of stern-posts it is only necessary to have one row of rivets for the rudder-trunk. Some builders and inspectors prefer to put two rows, but it is only waste of time doing so.

In the riveting of bosses, it is absolutely necessary to have the countersink bored out a sufficient depth, so that when the engineers have done boring and fitting in the stern-tube, there will be plenty of countersink left to hold the rivets secure.

In putting in the boss-rivets it is a good plan to cool them at the points, so that the heads may thereby be well tightened up.

Bear in mind that it will save trouble, and make better workmanship, if you arrange the plating so that a strake will cover the boss.

Make the scarf of your stern-post always on the port side, and do not have the length of the knee or keel portion to exceed 10 feet 6 inches, as that length is about as great as can be conveniently taken on ordinary trucks, if the post has to come by railway from the forge.

STEMS.

The mould for bending the stem too should be made off the inside line of stem; and if it is not turned before the scarfs of keel-bars are cut and finished, it is well to measure the total length of the keel on the blocks, and contract or increase the length of the stem-bar, as the case may require, to make up the exact length. Do not drill any holes in stem until it is turned to shape, and be careful to have the scarf on the right side to agree with forward length of keel-bar.

In forging stem-bars, have the fore-side shaped to a flat half-round, and see that there is no twist in the bar.

RUDDER-FRAMES.

Should you make the rudder forging in scantling, according to Lloyd's, bear in mind that if for a spar-deck ship, or vessel with full poop and forecastle, the diameter of the rudder-head must be in accordance with the dimensions given for the gross tonnage, and not the tonnage under main deck.

Attention should be paid to having the rudder-pintles all in a fair line. Have a steel washer for the pintle at heel of rudder to work on. It is always the best plan to make the rudder to unship, and the space for unshipping at each pintle should be about 1 inch deeper than the length of the pintle.

In a screw vessel attention should be paid to keeping the pintles clear of the bracket on the after-post for outside shaft bearing.

In rudder forging for vessels of from 200 to 500 tons, have a stay across centre of rudder from rudder-post to bow; and in vessels over that tonnage, two stays; width of stays about 3½ inches. The stays may either be made with the forging or of cast-iron fitted in. The space between the plates of rudder should be filled in with either wood or Portland Cement. Thickness of rudder-plates need in no case exceed ¼-inch; and it makes the most substantial work to have the rudder-plates snap-riveted.

RUDDER-BANDS.

Pay particular attention to see that the centre of the pintles are correctly set off before boring same, by striking a line up centres, to see if these are in a line, and that the back is straight and fair; this applies also to the stern-post. See that the rudder-trunk is made of sufficient size to allow the rudder-stock to be got up easily, say from 8 to 9 inches internal diameter for a 4 to 5-inch rudder-post; other diameters to be in like proportion. Attention should be paid to having the rudder-trunk and angle-iron binding the foot of trunk to outside plating a good fit, and the bottom carefully calked.

RUDDER-STOPS.

The proper angle for a rudder to travel is 42 degrees on each side of centre line of ship, and the stopper should be made to suit this. Be particular to have the stops made strong enough and well secured to stern-post. The rudder working easily is a matter of great importance, and requires particular attention in the lining-off and putting in place.

ANGLE-IRON FRAMES.

Previous to putting any work on the bars, have them examined to see that there are no cracks or blemishes, as angle-bars are constantly sent from the iron-works without care being taken to see if they are sound.

In punching the frames, see that the holes are properly divided; and as an example, for double-riveted laps with ¾-inch rivets, have the top hole 4½ inches from upper edge of lap, or 6½ inches from centre of lap, and the lower hole 3¾ inches from lower edge of lap, or 6 inches from centre of lap, on plate mark on the mould or board. Fig. 13 shows the proper spacing of rivets for double-riveted laps with ¾-inch rivets. *a*, is the frame; *b*, rivets to be as close to frame as head of rivet will permit; *c c c*, chain-riveting at butts to have the holes punched opposite each other; *d d*, butt-straps to be fitted as close as possible between laps of outside strakes.

In single laps have a hole punched 5½ inches each side of centre of lap, the lap being 2¾ inches. Divide the spacing of holes for rivets between one lap of plates and the next, as near to eight times the diameter of the rivet as you possibly can arrange.

In frames that run up to form sides of poop, forecastle, or bridge, have those with no beam on, cut off low enough to allow the lug-pieces for securing stringer-plate to shell to run from beam to beam, as Fig. 14, where *a a a* is the poop-deck stringer-plate; *b b*, lug; *c c*, beam knees; *d d d*, frames; *e e*, this hole to be made after the plating is on. A hole should be punched in head of the frames that are cut short for lug-pieces passing, about 3 in. down; but it is best not to put this in until the vessel is framed and faired.

Fig 13

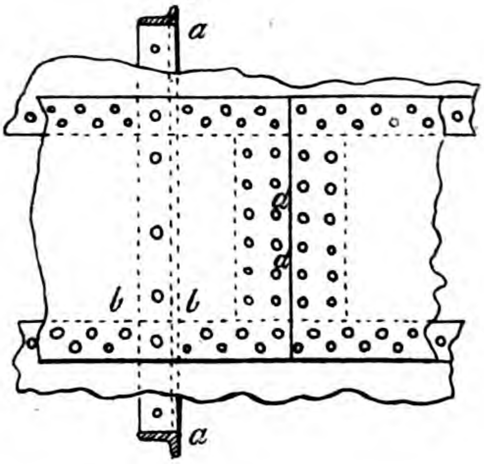


Fig 14

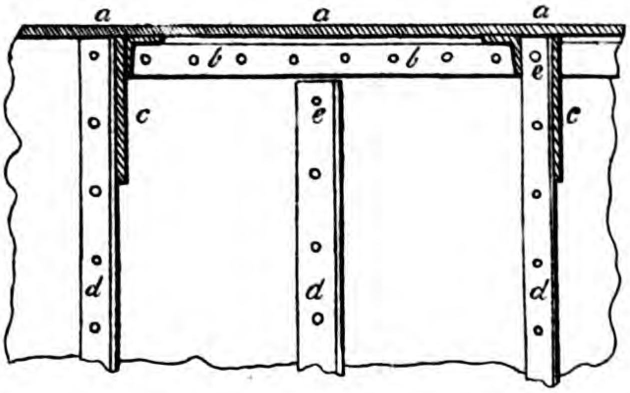


Fig 15

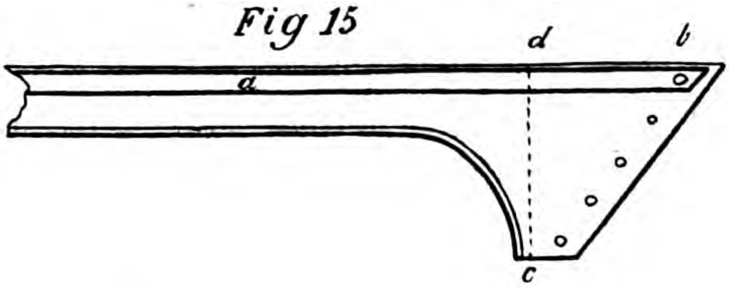
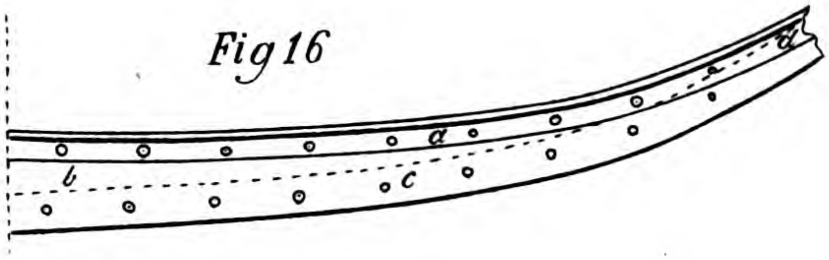


Fig 16



In frames that step on the knee of stern-post or stem, do not neglect to have them cut to the proper thickness to allow the plating to come on.

The heel of frames bearing on keel should be carefully cut and finished, so as to butt close together, and the bearance not to be greater in width than the thickness of keel, otherwise a proper job will not be made of the garboard strake.

The inside flange of angle-iron frame should be punched so as to suit size of the reverse frame, and care should be taken to see that the holes are so punched as to take the centre of flange of reverse frame.

It is necessary to see that the heel pieces are quite fair with under side of frames, and that they bear true on the keel. One or two holes only should be punched in the frames, for the beam-knee, prior to putting up the frames.

Length of beam-knee is measured square off, and the holes should be divided round the sweep, the centre of lower hole placed about 2 inches from lower edge of knee, Fig. 15, in which *a* is the reverse iron; *b*, hole punched to take reverse bar on beam; *c d*, measurement at right angles to top of beam—not obliquely. Do not have the upper hole in head of frame for upper rivet in beam-knee punched until the frames of vessels are all faired and sheered, as in case the beam requires to be lifted or lowered, it spoils the hole; and as this rivet passes through the angle-iron on beam it is necessary the hole should be true to make good work. The same rule applies to the bottom hole in beam-knee, as it looks very unworkmanlike to see a blind hole there.

The double frames at the bulkheads should be punched for rivets 4 inches centre to centre, and should be chipped at both edges previous to hoisting up in place, otherwise difficulty will be found in making a tight job of the calking.

If the vessel has a sheerstrake with jump joints, see that the holes punched in frames are clear of the lap of both the inside and outside sheerstrake.

REVERSE FRAMES.

The frames with no beams on to have the reverse bars running up to main deck height, and these to butt in centre of floor, having heel-pieces of angle-iron on opposite side of floor-top, of sufficient size to form top flange for keelson fastenings.

Short reverse frames to run up to upper turn of bilge; but if there is a spirketting plate on 'tween-deck stringer, then the short reverse frame should run up to top of said plate.

Butts of the short reverse frames should be about 4 feet each side of centre-line, alternately on the starboard and port side; but should these butts come in the way of boiler or other keelsons, the distance must be altered to suit.

Holes should not be punched in reverse frames in way of floor-ends, unless there is a clear space of ¾-of-an-inch from outside of rivet-hole to lower edge of reverse frame, as in Fig. 16, where *a* is the reverse bar; *b*, floor; *c*, frame; at *d* rivet this flush, and let reverse bar lie over it.

The reverse frames across the floor-tops at ends of vessel will require to be bevelled to suit the rise of floors and make a fair seat for the centre keelson. These bevels can best be taken when the vessel is ribanded and shored up.

See that the butts of the reverse frames are quite close and fair to each other. Accuracy of the workmanship adds greatly to the strength in all parts of an iron vessel.

The reverse frames must fit well over the floor-ends, and see that the floor-ends are thinned down to suit this.

The double reverse frame on floor-top should be neatly fitted on. Get a straight-edge, to see that it is fair, and attend to having all the scarfing or lug-pieces riveted close to floor plates.

ANGLE-IRONS ON BEAMS.

The holes must be punched to suit width of deck planks; the centre should be marked on the beam, and have two template battens made for marking the holes for punching in the angle-irons, so that they are equally spaced and divided. The holes for the fore-and-aft tie-plates and stringer-plates should also be set off on these battens, and the holes marked and punched accordingly. Holes for tie-plates and stringer must be punched to suit the diameter of rivets intended to be used, and those for the deck-plank to suit size of deck screws or bolts.

Holes should not be punched nearer to beam-ends on top flange of angle-iron on beam than about 6 or 7 inches, in case they should not come fair with the stringer angle-iron holes. These holes are best drilled through top flange of beam angle-iron, after the stringer is put on, the holes being previously punched in the stringer-plate.

One angle-iron only on beam to run out to beam-end, and to take a rivet through angle-iron on beam-knee and frame, Fig. 17. *a* is the reverse bar on beam; *b b*, frame; *c*, beam; *d d d*, rivets for stringer-plate, 6 inches or 7 inches apart; *e e e*, ditto for deck-plank twice the width of plank; *f*, stringer-plate.

The holes for riveting stringer-plate to angle-iron on beams should be about eight times the diameter of the rivets apart.

See that the angle-irons on beams are properly levelled at each end, so as to give a true seat on which to rivet the stringer plates.

FLOOR PLATES.

Floors should be twice the height above keel at floor-ends than they are at centre-line, and should be parallel to base-line athwartships, as far as practicable. Floor-plates at ends to be the width of inside flange of angle-iron frames.

See that the floor-ends are neatly thinned down, so that the reverse frames fit over fair and close.

Floor-plates should be sheared ½-inch less than the shape of frames.

The floor-ends where they have been thinned down for reverse frames should be chipped flush with the frame, both inside and out, previous to keelson or shell plating going on.

Limber-holes should be cut so as to clear frames, heel-pieces, lug-pieces for keelsons, intercostals, and so on.

At the extreme ends of vessel, the floor-plates should be increased in depth, to say twice the depth of floors amidships, or until they measure say 2 feet across the top, from outside to outside of frame.

Floor-plate for the transom-frame should be put on the depth of the knuckle, so that the stern timbers are sufficiently secured.

MAIN-DECK STRINGER.

In the case of an inside sheerstrake going up only to under side of main-deck stringer-plate, the holes in said stringer for the angle-iron bar will require punching the thickness of the inside sheerstrake nearer the outer edge of stringer-plate, so as to catch the centre of the bar, Fig. 18. *a*, reverse bar; *b*, beam; *c*, inside sheerstrake; *d*, outside sheerstrake.

Should the inside sheerstrake not run up above the main-deck stringer-plate, see that the stringer projects over the frames the full thickness of the inside sheerstrake.

Attention should be paid to punching the holes in stringer-plate for the angle-iron bar, to see that they are not punched with the same die as is used for the outside plating, no more countersink being required than is sufficient to keep the punch from choking, and the stringer-plates should be well sheered to form of side of vessel, or a bad bearing will be left for the gunwale angle-iron bars.

It is advisable to have the stringer-plates riveted to the beams, also the butt-straps riveted as soon as possible, and see that the butts come well clear of butts of sheerstrake.

Previous to commencing with main-deck stringer, see that the heads of frames and reverse frames are not higher than the beams.

Have all holes for the diagonal tie-plates in main-deck stringer-plates punched before putting in place. It is well in

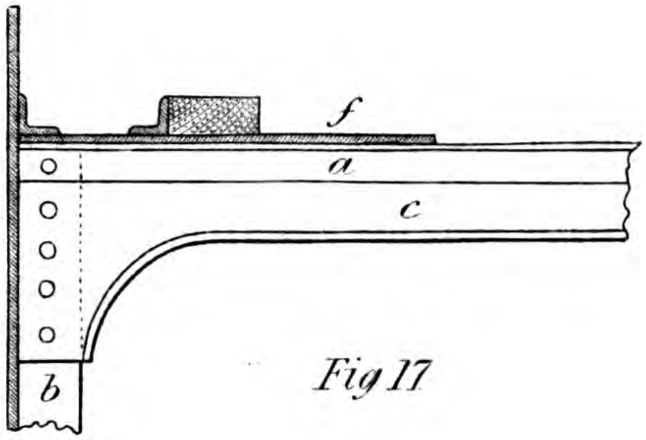


Fig 17

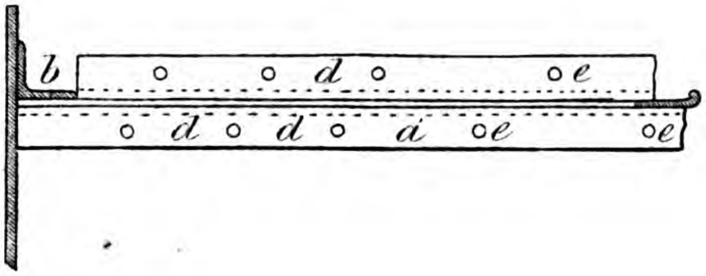


Fig 18

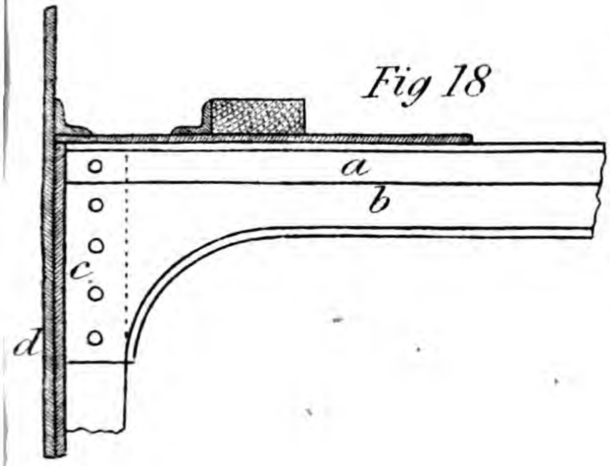


Fig 19

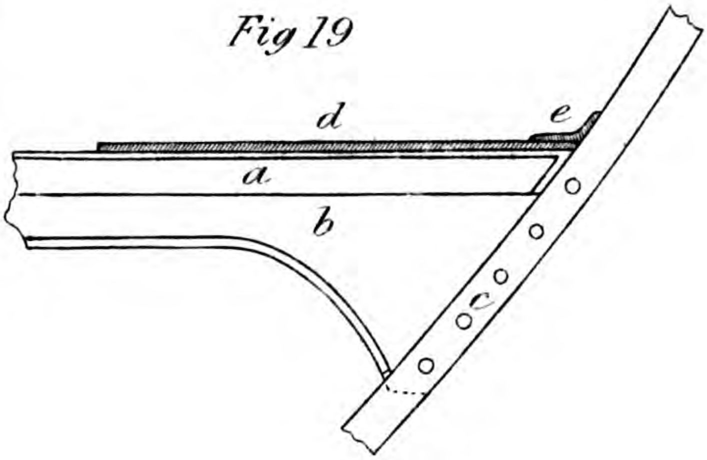
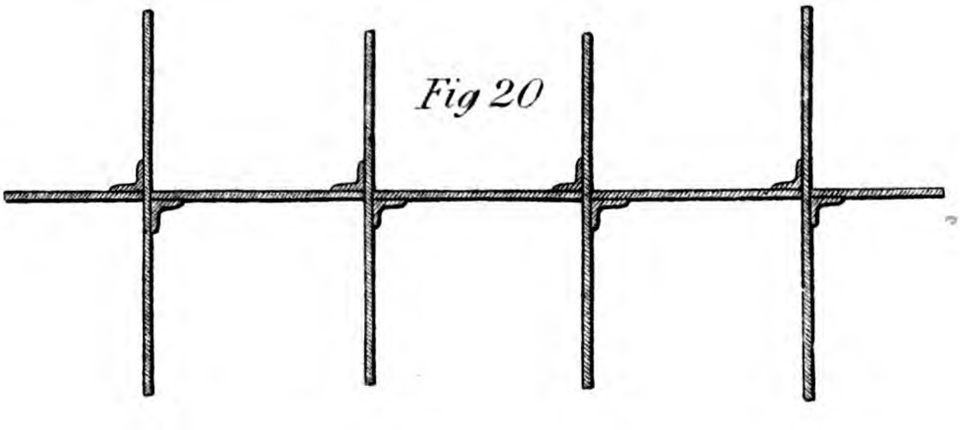


Fig 20



all cases to have the butts of main-deck stringers treble-chain riveted.

'TWEEN-DECK STRINGER.

Have all beams in and riveted before commencing to put in 'tween-deck stringers.

In vessels where the alternate reverse frames do not run up to height of hold-beams, see that holes are not punched in the vertical flange of stringer angle-iron, unless it is intended to rivet a lug-piece on the frame, for fastening the stringer angle-iron to the frames with no reverse bar running to that height.

In the after-peak, where there is a considerable flare in the sides of vessel, it is advisable to use a bar of larger dimensions for the stringer angle-iron, so as to get a good hole in the bar, not too near the edge, and thereby weaken it considerably. In Fig. 19, *a* is reverse bar; *b*, beam; *c*, frame; *d*, stringer-plate; *e*, rivet must not be too near edge of angle-iron, nor too far down in its bosom.

POOP-DECK STRINGER.

In putting on poop and forecastle deck stringers, have the stringer-plate sheered to come out to the outside edge of frames, so that when the forecastle or poop plating goes on it will butt up against it.

Holes should be punched in edge of centre stringer-plate aft for fastening plate, for taking rudder trunk, and fixing stuffing box round rudder-head to.

WASH-PLATES.

Do not put wash-plates between bulkheads and floor-plate on adjoining frames, so as to allow the water to get freely to the pumps.

Fitting in wash-plates between floors may be done as shown in Fig. 20; but if they are to serve as intercostal keelsons, four angle-irons at each floor will be necessary, and they must be made to fit close on.

BILGE-KEELSONS, &c.

In putting on the lug pieces for keelsons, see that they are quite fair with the edge of inside flange of angle-iron frame, and the fore-and-aft flange of reverse frame.

The lug-pieces should fit close against the frame angle-iron and be well riveted thereto.

In keelsons formed of two angle-irons with a bulb-iron, between, allow between the angle-irons a $\frac{1}{4}$-inch extra beyond the thickness of the bulb-iron, in marking off the holes for rivets in reverse frames and lug-pieces so far as the bulb iron extends.

The lug-pieces for three frames forward and aft of the finish of bulb-iron between angles should not be punched, but drilled to suit a tapered slip neatly fitted between the two keelson angle-bars.

The butts of angle-iron bars of keelsons should be so shifted as to be at least two spaces of frames clear of butts of other keelsons, and as far as practicable clear of butts of outside plating.

If the angle-irons for keelsons are 4 inches or more, the holes for rivets should be punched each side of the centre-line.

Athwartship flanges of bilge-keelson angle-irons in way of breasthooks should not be riveted till the breasthook-plate is in.

See that the breasthooks are got in as soon as possible, and that they are well fitted and securely riveted in place. A man-hole should be cut in breasthooks where necessary.

Should the breasthooks or pointers aft in a screw vessel not be high enough above the stern-tube, they should not be riveted until the boss for shaft is bored and finished, on account of leaving room for men fastening bolts, and so on.

Fig 22.

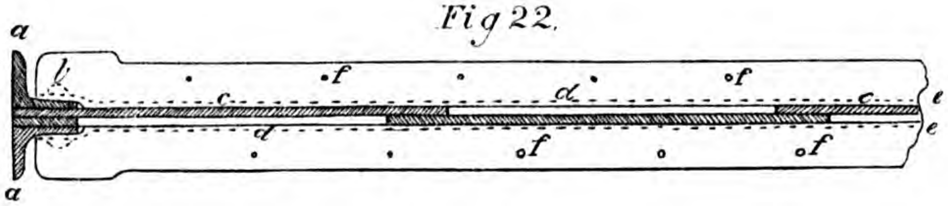


Fig 21.

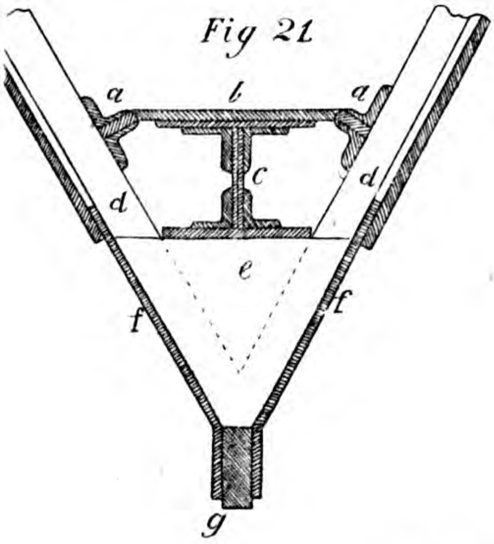


Fig 23.

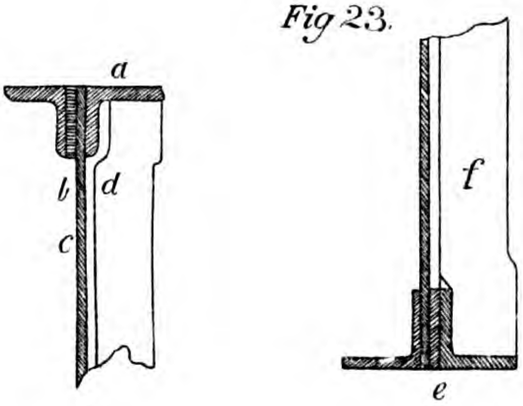


Fig 24.

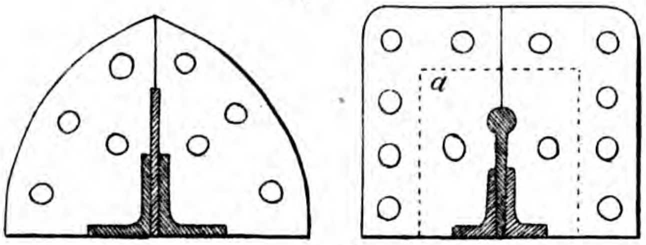
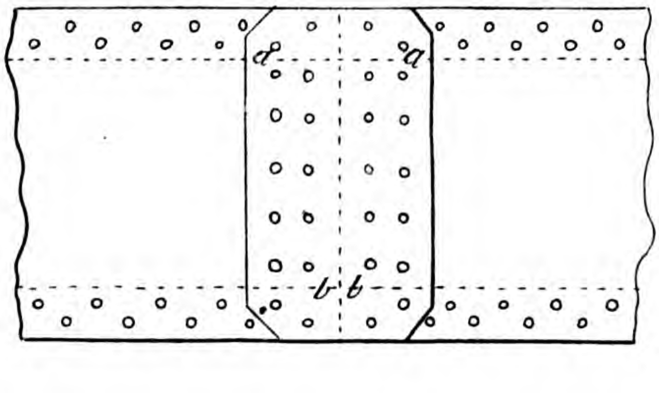


Fig 25.



Have the position of bilge-keelsons carefully marked off on frames, and see that they are sheared fair.

It is advisable to keep the bilge-keelsons clear of ribbons as far as possible, in case the lug-pieces or reverse frames want any setting up.

When practicable, have the height of lower bilge-keelsons at aft-peak bulkhead made to correspond with the height of top plate of centre keelson, so as to get a breasthook-plate riveted between the bilge-keelson angle-irons and top of centre keelson, Fig. 21, where *a a* show bilge keelsons; *b*, breasthook; *c*, centre keelson; *d*, frame; *e*, floor; *f*, garboard strake; *g*, keel. This makes a good finish and a very secure fastening.

BULKHEADS.

See that the bulkhead frames are all chipped fair on edges prior to putting up in place, so that the bulkhead plates can be properly calked under the shelf-plates, stringers, and so on.

The bulkhead plates should be calked outside between the frames as well as both sides inside, and round the edges of the gravit-plates, for keelsons passing through; see that the gravit-plates are a good fit and neatly put on. The plates for gravits should be $\frac{1}{8}$-inch thicker than the bulkhead plates.

The beam angle-bars should be cut short on bulkheads, so that they lie in the bosom of the bar, Fig. 22, and the angle-irons forming the beam on bulkhead should not be less than 3 inches deep, so that a good rivet may be got in through the head of the vertical angle-iron bar. *a*, Fig. 22, is the side frame; *b*, holes to be left blind and riveted after the rest of bulkhead; *c c*, bulkhead-plates; *d d*, slip to be set to curve of beam, and to equal angle-iron in depth; *e e*, the vertical flanges of these bars not to be less than 3 feet to get a good rivet in head of vertical bar; *fff*, holes to suit deck-planks. The vertical bars should have a hole for a rivet punched through both side frames, and should be neatly joggled for it at foot. The same applies to both the reverse angle-irons on the top edge, Fig. 23. *a*, beam's reverse bar; *b*, slip; *c*, bulkhead-plate; *d*, vertical bar, to be properly joggled over; *e*, side frame; *f*, vertical bar.

In plating bulkheads, attention should be paid to see that the first plate is at right angles with the keel; also see that the reverse angles forming the beam are not sagged down in centre or standing too high at centre or ends.

The fore-and-aft peak bulkheads should be plated in the vessel, after the frames are faired, not from the mould, or board, in case the frames may not be the proper fit at the bottom. This applies more especially to vessels with flat-plate keels.

Attention should be paid to the fitting and punching of the gravit-plates, to see that the holes are sufficiently close and regular, and that the plates are not made larger than necessary, as, if so, they cannot be calked tight. It is also advisable to have a rivet as close as practicable to the hole for keelson-bars passing through the bulkhead, Fig. 24. *a* in this figure indicates the position of boiler-keelsons in engine-room.

INSIDE SHEERSTRAKES.

The butts of inside sheerstrake should be double-riveted through inside sheerstrake and butt-strap; the row of rivets next butt of plate to be riveted flush before the outside sheerstrake is put on, Fig. 25. *a a*, these two rows, through inside and outside sheerstrakes, and butt-straps, and so on; *b b*, these two rows through inside sheerstrake, and butt-straps, and riveted flush, before outside plate is put on.

If there is only one frame between the butts of outside and inside sheerstrake, see that the plates are butted fairly in the centre, between frames. Same rule applies to the outside sheerstrake, so that there is a full frame space of shift between the butts of outside and inside sheerstrakes.

The holes for rivets in the gunwale angle-iron should not be punched with the same die as used for outside plating, on account of giving too much countersink.

In inside or ordinary sheerstrakes attention should be paid to seeing that the holes for the vertical flange of gunwale angle-irons are punched the proper height, so that the holes may be fair in the centre of bar.

OUTSIDE SHEERSTRAKES.

In outside sheerstrakes make sure that the gunwale angle-iron bars on the top edge of sheerstrake are properly faired all fore-and-aft, as also the top edge of the sheerstrake itself. If possible, it is well that the gunwale angle-bar should be not less than 4 inches by 4 inches, as this width will give a better chance of making all fair holes.

BEAMS.

The beam-mould should be made the full breadth of the vessel, so that the total length of beam can be taken off and the correct bevel taken at both sides. The mould should be made the full depth of the beam-knees.

Have the bottom hole for rivet in the beam-knee punched, so as to allow 1½ inches of iron from the under side of rivet to bottom of knee.

POOP-BEAMS.

Have the poop-beams put up and bolted to the frames, but do not have them riveted until after the stringer-plates and tie-plates are all faired and riveted. This should be specially attended to, as it frequently occurs that if the beams are riveted first the knees get twisted, and set the beams up or down, as the case may be, making bad and unfair work of the stringer and tie plates.

To keep the poop-beams the proper spacing it is a good plan to have a long plank, say in scantling, about 8 inches by 3 inches or 2½ inches, and have marked off on this plank the spacing of the beams, cutting out a notch for each beam; and when the beams are put up let them go into the notches, and have the plank shored up from main deck. By attending to this you will have all your beams equal distances and to one curve, which will add considerably to the appearance of the cabin ceiling, and so on.

FRAMING OF HATCHES, &c.

In making hatches, put in the fore-and-aft angle-iron bars first; have them made a good and neat fit; see that they are straight fore-and-aft, and then put in the bulb-iron or plate for fore-and-aft carlings; seeing this is also a good fit.

An angle-iron bar, about 5 inches by 5 inches by ½-inch, cut in lengths to suit, and fitted in the corners of the hatches, makes a much better finish than to knee the bulb-iron or bend the plate-knee.

The beams that form the fore-and-aft ends should have reverse angle-irons, not less than 3 inches deep, so that the holes in plate-knees may be punched to allow ¾-of-an-inch of iron from top of rivet-hole to top of knee-plate.

OUTSIDE PLATING.

Attention should be paid to having the butts of the garboard strake clear of the scarfs in keel, and that the butts of the garboard plates should have three frames between them from the starboard to the port side throughout, Fig. 26. *a a*, the butts of these go a frame farther forward on starboard side (see *f f*); *b b*, the butts of these do the same (see *e e e*); *c c*, butts (see *f f*); *d d*, garboard-strake butts (see *e e e*).

Fig 26

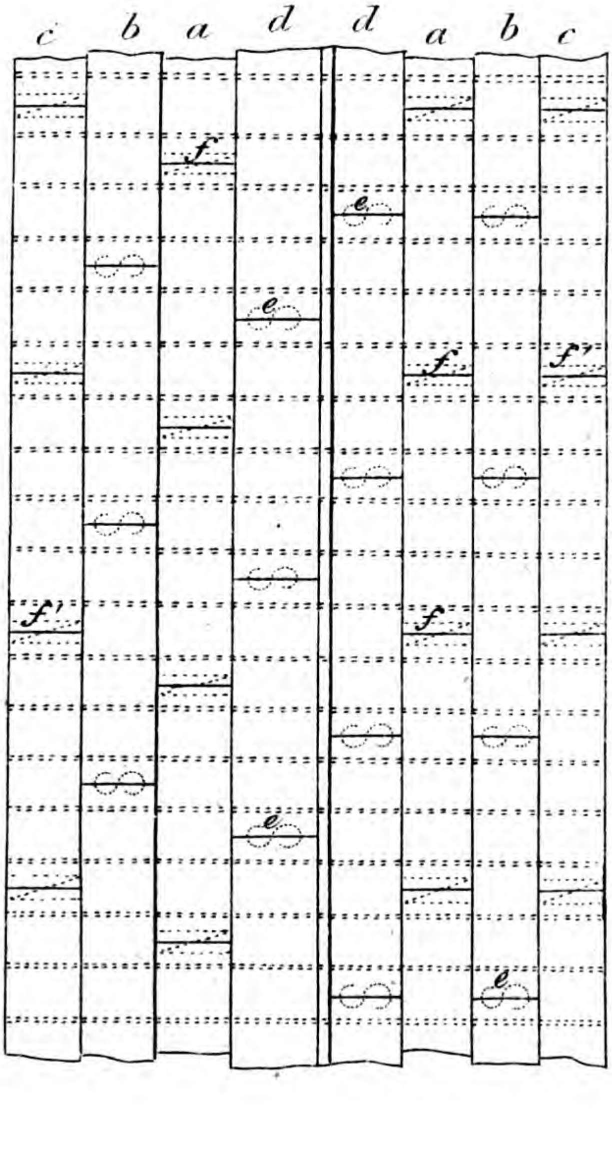


Fig 27

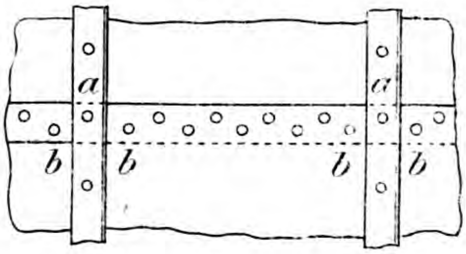


Fig 28

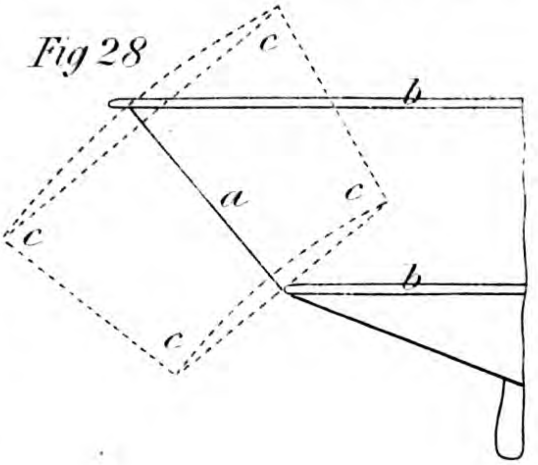
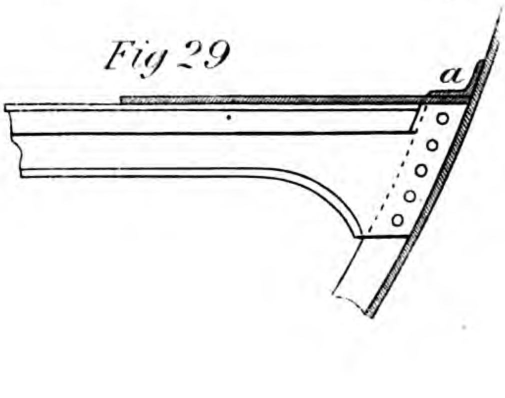


Fig 29



In order to have the butts of the outside plating a clear two spaces from the bulkheads, have the plates that come in wake of bulkheads a space of frames more in length than the average length of plating.

Have the sides of plates, with the maker's stamp on, put to the outside of ship, so that the surveyor may see it, on account of the classification.

In the butts of bilge strakes, if the bilge is at all quick, the edges of the plates should be sheered with a slight curve.

In plating vessels, attention should be paid not to put too much weight of plating on the top sides until the garboard bilge and bottom is all plated and riveted.

The holes for rivets in the lower edge of double riveting should be punched as near as possible to the edge of frame, Fig 28, and spaced, say for a 3-inch flange and $\frac{3}{4}$-inch rivets, not more than 8-inch pitch. *a a* are the frames; *b b* rivets next frames, to be as shown.

Have the inside strakes stitched at the butt straps and frames, say about 6 rivets in each butt-strap and two in each frame, before putting on the outside strakes.

The filling-plates at the bulk-heads at back of shell-plates should be at least the width of the fore-and-aft flange of the frame angle-iron longer than two spaces of frames, in the fore-and-aft peak bulkheads, the filling-plates will be about 3 inches longer on account of the set and bend.

In the plating round the knuckle of stern, see that the plates are kept up to the sheer-marks, and on no account have them below, and allow a clear $1\frac{1}{4}$ inch from top of rivet-hole to the edge of plate.

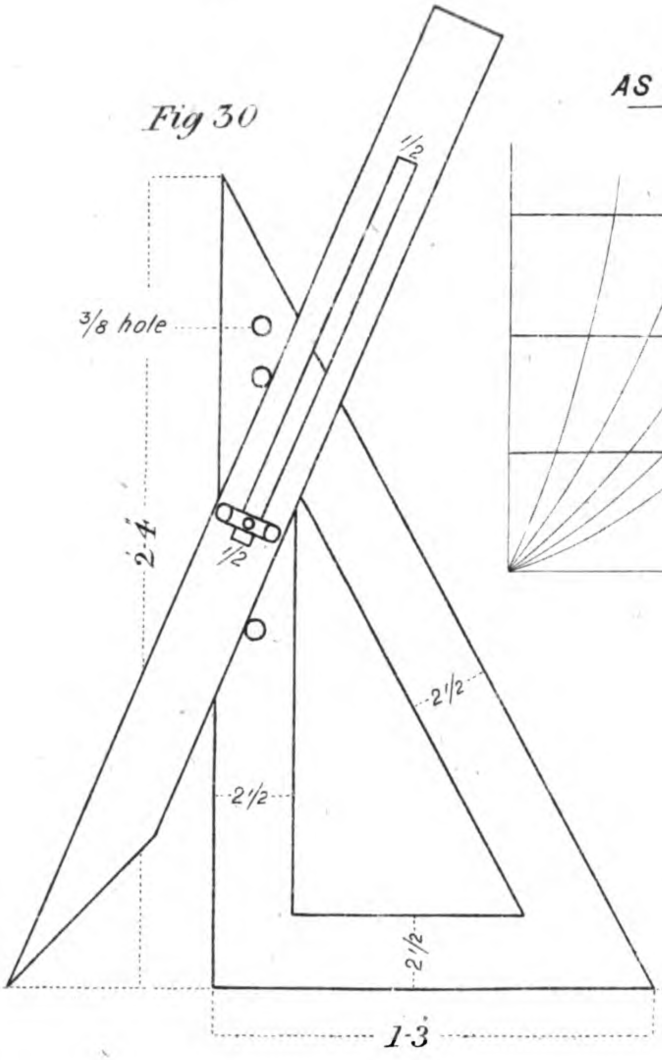
In taking off the dimensions to order plates for going round the stern, supposing them to be of average size, an allowance of about 5 inches should be made beyond what the plate measures in the depth of the stern. In Fig. 28, *a* is the centre of plate; *b b*, mouldings; *c c c*, development of plate, showing allowance.

In marking the rivet-holes for sheerstrakes aft, attention should be paid to having the holes for connecting the stringer-plate to the shell of the vessel high enough up for the rivet-hole to come in the centre of the flange of the angle-iron, Fig. 29. *a*, see that this rivet is not too low in bosom of angle-iron.

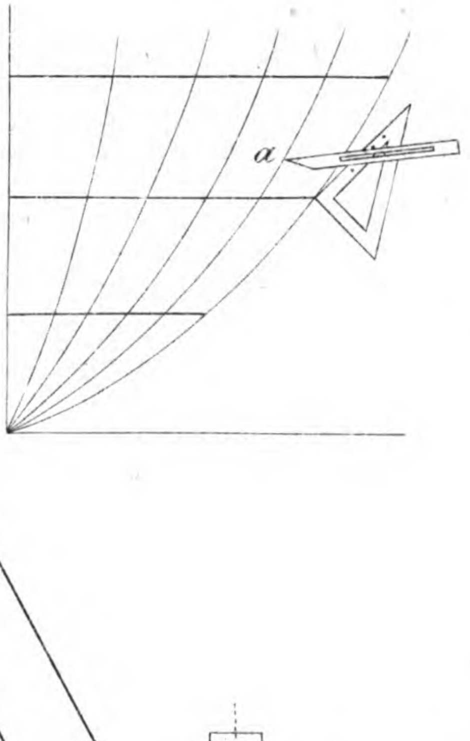
In the plating of topgallant forecastles, the plate that is cut for the knightheads should project, say about 3 inches beyond the knighthead bulkhead, and the rivets through the bulkhead should be flush on the forward side. The projection is to allow for bolting on the knee brackets, and so on.

FRAME BEVELLER.

Fig 30



AS APPLIED



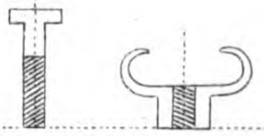
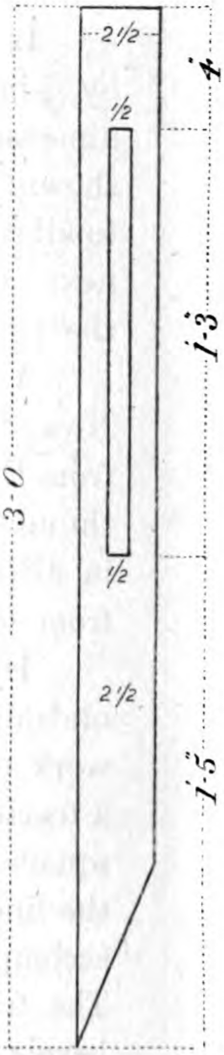


Fig 31



FRAME BEVELLER.

Fig. 30 represents a very useful instrument for acertaining the bevels for ships' frames, which can be relied upon as being perfectly correct. It is used in most of the ship-yards on the north-east coast of England, not only for the frames, but for getting the bevels of flooring tops, fore-and-aft, also the centre keelsons.

It consists of a right-angled triangle made of iron, 2½ in. by ¼-inch thick; also a straight piece of iron of the same dimensions, Fig. 31, with the bottom part cut to a bevel, as shown. On the top there is a long hole cut sufficiently wide to allow a ⅜-inch thumbscrew to slide up and down in it. You next require a short ⅜-inch bolt and a thumbscrew to fasten the two together.

You will see some holes in the right-angled triangle. Now, if your frames are to be 1 ft. 8 in. apart, the distance from the heel of the square to the centre of the hole where the thumbscrew is shown *must be the same;* and this rule applies in all cases, it matters not what distance the frames are one from the other.

How to ascertain the bevels. Commencing with the midship frames, in which there would be no bevels, you then work towards either stem or stern, and as soon as you come to a frame that requires bevelling you would place the heel of the square on the line of the last frame done; and the point *a* on the line of the frame you where about to bend, as shown in the accompanying figure. This would give you the required bevel. The frame beveller applied in this manner will give you the bevels at any part of the frames, always remembering to place the heel of the square on the line outside the one for which you are going to bend the frame, and the point of the bevel on the one you are going to work to.

DIMENSIONS OF ANGLE-IRON FOR ALL GRADES OF VESSELS.

Gross Tonnage.						Inches.		
100	and under	200	=	2½	×	2½	×	$\frac{6}{16}$
200	"	300	=	3	×	2½	×	$\frac{6}{16}$
300	"	400	=	3¼	×	2¾	×	$\frac{6}{16}$
400	"	500	=	3½	×	2¾	×	$\frac{7}{16}$
500	"	600	=	3¾	×	2¾	×	$\frac{7}{16}$
600	"	700	=	4	×	3	×	$\frac{7}{16}$
700	"	800	=	4¼	×	3	×	$\frac{8}{16}$
800	"	900	=	4½	×	3	×	$\frac{8}{16}$
900	"	1000	=	4¾	×	3	×	$\frac{8}{16}$
1000	"	1200	=	5	×	3	×	$\frac{9}{16}$
1200	"	1500	=	5	×	3½	×	$\frac{9}{16}$
1500	"	2000	=	5½	×	3½	×	$\frac{10}{16}$
2000	"	2500	=	6	×	4	×	$\frac{10}{16}$
2500	"	3000	=	6¼	×	4	×	$\frac{11}{16}$
3000	"	3500	=	6½	×	4	×	$\frac{11}{16}$

REVERSE ANGLE-IRONS ON FRAMES, BULKHEADS, AND BOX KEELSONS, FOR ALL GRADES.

Gross Tonnage.						Inches.		
100	and under	200	=	2¼	×	2¼	×	$\frac{5}{16}$
200	"	300	=	2¼	×	2¼	×	$\frac{5}{16}$
300	"	400	=	2½	×	2½	×	$\frac{5}{16}$
400	"	500	=	2¾	×	2½	×	$\frac{6}{16}$
500	"	600	=	3	×	2½	×	$\frac{6}{16}$
600	"	700	=	3	×	2¾	×	$\frac{6}{16}$
700	"	800	=	3	×	2¾	×	$\frac{7}{16}$
800	"	900	=	3	×	3	×	$\frac{7}{16}$
900	"	1000	=	3¼	×	3	×	$\frac{7}{16}$
1000	"	1200	=	3½	×	3	×	$\frac{8}{16}$
1200	"	1500	=	3½	×	3	×	$\frac{8}{16}$
1500	"	2000	=	4	×	3½	×	$\frac{9}{16}$
2000	"	2500	=	4½	×	3½	×	$\frac{9}{16}$
2500	"	3000	=	4½	×	3½	×	$\frac{10}{16}$
3000	"	3500	=	4½	×	3½	×	$\frac{10}{16}$

THICKNESS OF OUTSIDE PLATES, GARBOARD STRAKES, AND SINGLE PLATE; MIDDLE-LINE KEELSONS STANDING UP ON FLOORS.

Gross Tonnage.		Inches.		
100 and under 200	...	$\frac{8}{16}$	...	$\frac{7}{16}$
200 ″ 300	...	$\frac{9}{16}$	...	$\frac{8}{16}$
300 ″ 400	...	$\frac{10}{16}$	...	$\frac{9}{16}$
400 ″ 500	...	$\frac{10}{16}$	...	$\frac{9}{16}$
500 ″ 600	...	$\frac{11}{16}$	...	$\frac{10}{16}$
600 ″ 700	...	$\frac{11}{16}$	...	$\frac{10}{16}$
700 ″ 800	...	$\frac{12}{16}$	...	$\frac{11}{16}$
800 ″ 900	...	$\frac{12}{16}$	...	$\frac{11}{16}$
900 ″ 1000	...	$\frac{13}{16}$	...	$\frac{12}{16}$
1000 ″ 1200	...	$\frac{13}{16}$	...	$\frac{12}{16}$
1200 ″ 1500	...	$\frac{14}{16}$	...	$\frac{13}{16}$
1500 ″ 2000	...	$\frac{14}{16}$	...	$\frac{13}{16}$
2000 ″ 2500	...	$\frac{15}{16}$	...	$\frac{14}{16}$
2500 ″ 3000	...	$\frac{15}{16}$	...	$\frac{14}{16}$
3000 ″ 3500	...	$\frac{16}{16}$	...	$\frac{15}{16}$

FROM GARBOARD TO UPPER PART OF BILGE AND THE SHEER-STRAKES.

Gross Tonnage.		Inches.		
100 and under 200	...	$\frac{7}{16}$	...	$\frac{6}{16}$
200 ″ 300	...	$\frac{8}{16}$	...	$\frac{7}{16}$
300 ″ 400	...	$\frac{9}{16}$	...	$\frac{8}{16}$
400 ″ 500	...	$\frac{9}{16}$	...	$\frac{8}{16}$
500 ″ 600	...	$\frac{10}{16}$	...	$\frac{9}{16}$
600 ″ 700	...	$\frac{10}{16}$	...	$\frac{9}{16}$
700 ″ 800	...	$\frac{11}{16}$	...	$\frac{10}{16}$
800 ″ 900	...	$\frac{11}{16}$	...	$\frac{10}{16}$
900 ″ 1000	...	$\frac{12}{16}$	...	$\frac{11}{16}$
1000 ″ 1200	...	$\frac{12}{16}$	...	$\frac{11}{16}$
1200 ″ 1500	...	$\frac{13}{16}$	...	$\frac{12}{16}$
1500 ″ 2000	...	$\frac{13}{16}$	...	$\frac{12}{16}$
2000 ″ 2500	...	$\frac{14}{16}$	...	$\frac{13}{16}$
2500 ″ 3000	...	$\frac{14}{16}$	...	$\frac{13}{16}$
3000 ″ 3500	...	$\frac{15}{16}$	...	$\frac{14}{16}$

From Upper Part of Bilge to a Perpendicular Height, from Under Side of Keel of Three-fifths the Internal Depth of Hold, Measured from the Upper Side of Upper Deck in all Ships, whether Spar-decked or otherwise.

Gross Tonnage.			Inches.	
100	and under	200	$\frac{6}{16}$	$\frac{5}{16}$
200	"	300	$\frac{7}{16}$	$\frac{6}{16}$
300	"	400	$\frac{8}{16}$	$\frac{7}{16}$
400	"	500	$\frac{8}{16}$	$\frac{7}{16}$
500	"	600	$\frac{9}{16}$	$\frac{8}{16}$
600	"	700	$\frac{9}{16}$	$\frac{8}{16}$
700	"	800	$\frac{10}{16}$	$\frac{9}{16}$
800	"	900	$\frac{10}{16}$	$\frac{9}{16}$
900	"	1000	$\frac{11}{16}$	$\frac{10}{16}$
1000	"	1200	$\frac{11}{16}$	$\frac{10}{16}$
1200	"	1500	$\frac{12}{16}$	$\frac{11}{16}$
1500	"	2000	$\frac{12}{16}$	$\frac{11}{16}$
2000	"	2500	$\frac{13}{16}$	$\frac{12}{16}$
2500	"	3000	$\frac{13}{16}$	$\frac{12}{16}$
3000	"	3500	$\frac{14}{16}$	$\frac{13}{16}$

From Three-fifths the Depth of Hold (Measured from the Upper Side of Upper Deck in all Ships, whether Spar-decked or otherwise) in Lower Edge or Sheerstrake.

Gross Tonnage.			Inches.	
100	and under	200	$\frac{6}{16}$	$\frac{5}{16}$
200	"	300	$\frac{6}{16}$	$\frac{5}{16}$
300	"	400	$\frac{7}{16}$	$\frac{6}{16}$
400	"	500	$\frac{7}{16}$	$\frac{6}{16}$
500	"	600	$\frac{8}{16}$	$\frac{7}{16}$
600	"	700	$\frac{8}{16}$	$\frac{7}{16}$
700	"	800	$\frac{9}{16}$	$\frac{8}{16}$
800	"	900	$\frac{9}{16}$	$\frac{8}{16}$
900	"	1000	$\frac{10}{16}$	$\frac{9}{16}$
1000	"	1200	$\frac{10}{16}$	$\frac{9}{16}$
1200	"	1500	$\frac{11}{16}$	$\frac{10}{16}$
1500	"	2000	$\frac{11}{16}$	$\frac{10}{16}$
2000	"	2500	$\frac{12}{16}$	$\frac{11}{16}$
2500	"	3000	$\frac{12}{16}$	$\frac{11}{16}$
3000	"	3500	$\frac{12}{16}$	$\frac{11}{16}$

THICKNESS OF STRINGER PLATES UPON BEAMS, FLOOR PLATE, HOOKS, CRUTCHES, AND BOX, OR INTERCOSTAL KEELSONS, FOR ALL GRADES.

Gross Tonnage.			Inches.	Gross Tonnage.			Inches.
100	and under	200	5/16	900	and under	1000	10/16
200	"	300	6/16	1000	"	1200	10/16
300	"	400	7/16	1200	"	1500	11/16
400	"	500	7/16	1500	"	2000	11/16
500	"	600	8/16	2000	"	2500	12/16
600	"	700	8/16	2500	"	3000	12/16
700	"	800	9/16	3000	"	3500	12/16
800	"	900	9/16				

THICKNESS OF PLATES OF BULKHEADS, FOR ALL GRADES.

Gross Tonnage.			Inches.	Gross Tonnage.			Inches.
100	and under	200	7/16	900	and under	1000	7/16
200	"	300	4/16	1000	"	1200	7/16
300	"	400	5/16	1200	"	1500	7/16
400	"	500	5/16	1500	"	2000	8/16
500	"	600	6/16	2000	"	2500	8/16
600	"	700	6/16	2500	"	3000	8/16
700	"	800	6/16	3000	"	3500	9/16
800	"	900	6/16				

DIMENSIONS OF ANGLE-IRON ON BEAMS, STRINGERS, OR KEELSONS FOR ALL GRADES.

Gross Tonnage.			Inches.				
100	and under	200	3	×	3	×	6/16
200	"	300	3	×	3	×	6/16
300	"	400	3½	×	3	×	6/16
400	"	500	4	×	3	×	6/16
500	"	600	4¼	×	3¼	×	7/16
600	"	700	4½	×	3½	×	8/16
700	"	800	4¾	×	3¾	×	8/16
800	"	900	5	×	4	×	9/16
900	"	1000	5	×	4¼	×	9/16
1000	"	1200	5	×	4½	×	9/16
1200	"	1500	5½	×	4¾	×	9/16
1500	"	2000	6	×	5	×	10/16
2000	"	2500	6½	×	5½	×	10/16
2500	"	3000	6½	×	5½	×	10/16
3000	"	3500	6½	×	5½	×	13/16

RUDDER FOR ALL GRADES.

Gross Tonnage.	Diameter at Head Inches.	Diameter at Heel. Inches.	Thickness of wood flat of Upper Deck. Inches.
100 and under 200	3	2	2½
200 " 300	2	2	2½
300 " 400	3¾	2¼	3
400 " 500	4½	2½	3
500 " 600	4½	2¾	3½
600 " 700	4¾	2¾	3½
700 " 800	5	3	3½
800 " 900	5¼	3	3½
900 " 1000	5½	3	4½
1000 " 1200	5¾	3	4
1200 " 1500	6	3¼	4
1500 " 2000	6½	3½	4
2000 " 2500	7¼	3¾	4
2500 " 3000	7¾	4	4
3000 " 3500	8	4½	4

The scantlings given are intended for ships, the length of which measured from the fore part of the stem to the after part on the stern-post in the range of the upper deck, does not exceed seven times their breadth, or ten times their depth of hold, taken from the upper part of the floors to the top of the upper deck beams.

DIAMETER OF RIVETS REQUIRED FOR THICKNESS OF PLATES.

Diameter of Rivets ...	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
Thickness of Plates ...	$\frac{5}{16}$ $\frac{6}{16}$ $\frac{7}{16}$	$\frac{8}{16}$ $\frac{9}{16}$ $\frac{10}{16}$	$\frac{11}{16}$ $\frac{12}{16}$ $\frac{13}{16}$	$\frac{14}{16}$ $\frac{15}{16}$ $\frac{16}{16}$

Rivets to be $\frac{1}{4}$-of-an-inch larger in diameter in the stern, stern-posts, and keel.

KEEL STEM AND STERN POSTS, FOR ALL GRADES.

Gross Tonnage.	Inches.
100 and under 200	6 × 1½
200 〃 300	6¼ × 2
300 〃 400	6½ × 2¼
400 〃 500	6¾ × 2½
500 〃 600	7 × 2½
600 〃 700	7 × 2¾
700 〃 800	7¼ × 2¾
800 〃 900	7½ × 3
900 〃 1000	8 × 3
1000 〃 1200	8½ × 3
1200 〃 1500	9 × 3
1500 〃 2000	10 × 3
2000 〃 2500	12 × 3
2500 〃 3000	12 × 3¼
3000 〃 3500	12 × 3½

FRAMES.

Distance of frames from moulding edge to moulding edge, all fore-and-aft, for all grades.

If single frames be adopted, the space from centre to centre is not to exceed 21 inches, all fore-and-aft, but provided an additional frame, for half the vessel's length amidships, be fitted at opposite side of each floor across the keel, and extended to upper part of bilges, and riveted through floor-plates and main frames, also through the outside plating, as required for main frames. The space may be increased to 23 inches in ships under 1000 tons, and to 24 inches in ships of 1000 tons and upwards.

STRAIN ON FLOATING VESSELS.

Floating vessels or ships are exposed to various strains which so much resemble those to which architectural and engineering constructions are subject that we may here profitably allude to them and the structural means by which they are resisted. The mechanical principles concerned in shipbuilding are so allied to those of ordinary building and construction that we may look upon the problems hitherto discussed as absolutely necessary to the investigation of those which engage the shipbuilder. The latter, it is true, are more complex, as in the various strains a ship is exposed to in a rolling sea, and, indeed, the researches and mathematical acumen which have been lately brought to bear upon them have still left the effects of the motions of heaving, rolling, and pitching in a very obscure light. In fact, to estimate with anything like accuracy the forces acting upon a ship in a rough sea is at present impossible, and shipbuilders are content to follow the best models and to be guided mainly by experience. Let us briefly refer to a few of the more obvious strains to which a ship is exposed when in still water. A ship has been compared to a girder, and may be imagined to rest only at two extreme points, as she may do when she takes the ground, or a ship may be supported in the middle of her length. These positions have been taken by ships in extreme cases, but the shipbuilder generally regards the strains to which she may be subject when afloat. A floating body, as is well known, receives an amount of upward pressure equal to the weight of water displaced. Now, every ship is subject to two well-known pressures which tend to change her form: "hogging" or arching, and "sagging" or bending down in the middle—one being the exact opposite condition of the other. Now "hogging," as it is termed, is due to the unequal buoyancy or upward pressure of water exercised at the ends, and in the centre portions of a ship's length—that is to say, at the bow and stern of a ship there is less upward pressure than weight owing to the fineness or sharpness of the vessel at those points; whereas at the centre portion, where she is widest, the buoyancy is in excess of the weight. This unequal distribution of upward pressure, compared to the ship's weight, occasioned by the shape of the bottom, tends to make the ship droop at its ends, for it must be evident the sum of the weights at the bow and stern must exactly equal the sum of the upward pressures in the middle. This kind of change in form has often been noticed in wooden ships, the opposite tendency to "sag." being manifest in long vessels where a great part of the weight, as the engines, is concentrated in the centre. These are the two commonest kinds of strain to which a ship is exposed, but there are others which more or less neutralise these; in fact, the mode of lading a vessel has a great deal to do with the strains. The stowage at one time may be in the centre, at other times at the ends—thus producing sagging amidships, or hogging, as the case may be. A long vessel is subject to a combination of these strains. Thus the ends might droop from excess of weights, and the engines or stowage of cargo may cause the amidship portion to droop also, thus causing intermediate points to rise by upward pressures, and producing a line of compound flexure which may be compared to a beam loaded in the centre and at the ends and supported at intermediate points. It will be seen, in such a case as the above, the strains are neutralised, for the sagging amidships is counterbalanced by the hogging strains at the ends. A ship is exposed then to local as well as general strains, and much depends on the way she is loaded. But a ship labouring in a heavy sea has a variety of strains and counter-strains. At one moment she may be carried upon the crest of a wave, at another moment carried on a trough of the sea; hence the points of support may be suddenly changed, producing a racking and contrary strain to which the static structures of the architect and engineer are not exposed. Thus the shipbuilder requires to give his vessel more than the rigidity the architect or engineer would his girder or roof, which has always the same strains to bear. Now, keeping in view a girder, let us see how a ship resists these strains. We have shown what portions of a girder most effectively resist the bending strains, and what portion is least employed; we have seen that the material is thrown into flanges at the upper and lower parts of the section and reduced to a minimum, particularly in the lattice girder in the centre part or web. A ship is a hollow girder, and, as we have seen, has similar bending strains, though the parts most subject to them are variously employed, at one time resisting compression, and at another time tension. Thus in the hogging strains the upper decks act to resist extension, and the lower parts or bottom of the vessel resist compression. Under sagging strains this is reversed. The centre parts are least strained when the ship is in its upright normal condition, but in a rough sea the side-plating or planking becomes liable to similar strains whenever the ship lurches. These bending strains, as we have seen, may take place at any point in the length of a ship; and as the section is widest in the middle, and tapers to the ends, the strength may be thought to be in the same proportion; but although the planking and timbers are made larger amidships, the fact of vessels often breaking up in the middle shows that they are not always the strongest there. Let us see what parts are best calculated to resist the longitudinal strains. The beams of a ship are placed transversely and do not help, but the upper deck and the bottom really form the two important resisting parts corresponding to the flanges of a beam. Again, the planking or skin of the vessel corresponds to the web of a hollow girder and aids in the strength. A ship, in fact, is a tubular girder tapering from the midship section to each end in width, but not in depth, and it has become a disputed point with shipbuilders how much reduction in the scantlings near the bow and stern is necessary to equalize the strength. This, however, is a more complex question than the diminution required in a beam of uniform strength, which can be calculated to a nicety. It is asserted by shipbuilders that the greatest strain is not at the midship section, but considerably before or abaft it. This may be so under certain conditions, but we believe the midship section is liable to the greatest nominal strain, or we should not have so many indications of the fact forced upon us in wrecks and collisions. But we have to notice another kind of strain—viz., the transverse—which often disarranges the form of a ship. Iron-plated vessels, for instance, are exposed to a wrenching or sheering strain, or each half of the midship section is subject to a double or twisting force, one being the weight of the ship's side acting through the centre of gravity—and when iron-plated this is considerable—and the upward buoyant pressure of the water near the centre of the section. How these strains are best met in the construction of ships we will not explain here, but will do so further on.

We have shown that the ship is exposed to strains which tend to break or bend her lengthwise, and also to change the form of her cross section. The latter we showed to be the action downward of the weight or side of the vessel together with the buoyancy of her middle part, acting upwards and constituting together a double and contrary action at each side of the centre line of the cross section, mechanically called "a couple." When a ship takes the ground and is supported on the keel, this transverse rocking action is increased, the leverage between the direction of the "up" and "down" forces being greater than they would act in the centre line of the section through the keel and at the side of vessel through the plating.

Now these various strains have to be met, and what do we find to be the means used in the ordinary ship? If we look at the section of a ship's hull, which is a kind of frame, we shall see that, to prevent these strains from producing change of form, there are the transverse beams and the frames, and the pillars fitted between the decks, which act as rigid bars to prevent the collapse of the decks. It will be very clear, on a little consideration, that, besides these parts being rigid, their connections should be carefully formed so that no rocking motion caused by the roll of the ship on its taking ground would be such as to weaken them. For example, the connection of the beams and frames is a most important one; and the shipbuilder has to bestow particular attention on this framing of his structure. The employment of bulkheads transversely placed is unquestionably the scientific and most direct way of meeting transverse strain and preventing change of sectional form; but unfortunately they are frequently neglected, or are placed more for convenience of storage and other considerations than as great structural expedients. To meet local strains caused by weights, the masts, the engines, and other requirements, special provisions have to be made to distribute these loads upon large bearing surfaces of the hull by the aid of bearers and cross pieces, "steps" and other means. Let us briefly notice the ordinary methods adopted to give rigidity to the hull, first speaking of the skeleton structure, and next of the "skin" or plating. The introduction of iron has greatly developed the structural science of shipbuilding. However well a wooden frame, connected by one of the ordinary modes of butting, dowelling, scarfing, &c., may resist compressive strains, it is comparatively weak to bear tensile strain. Every frame or rib of a wooden ship is composed of timbers butted or hook-scarfed together at the ends. In iron vessels the ribs can be rolled and bent to any curvature, and the simplest kind of "cap-joint" rivet through, or a "but-joint" with a "butt.strap" or cover-plate, gives a far greater resistance to tensile strain than can possibly be attained with a wooden joint. An iron "rib" or angle-iron can be made in one length to the required curve from keel to gunwale, while the deck beams, instead of being of rectangular section, as in the case of timber ships, may be of rolled iron or flanged section, or of plate-iron with riveted angle-irons, the same as employed in ordinary buildings. The facilities of welding also are of considerable value. Now, in the framing of wooden ships, the frames are of different pieces and scantlings; those near the keel are thicker and deeper, while the portions of the rib near the gunwale are of slighter scantling. These timbers are placed in pairs, and are technically known as the "frame" and "filling frame," and the combined timbers have a space between. The pieces making up each frame in length, or the "futtocks," and are so arranged that the butts break joint, or "give shift" to each other. Now, the strength of the vessel to resist the pressure of the water and any unequal strain, as when it took the ground, greatly depends on securing this shift of the butts. As a rule there are three whole or passing timbers between the heads or butts of the adjacent futtocks. But with all this skill in arranging the pieces of timber and the sets of ribs, there is little strength of a direct kind, the only means of retaining the shape being afforded by the planking or skin, and by long bolts passing through the ribs to secure them to each other (frame bolts as they are called), being square in section, driven fore-and-aft through three or more timbers. These bolts greatly assist in binding together the transverse frames, and giving stiffness to the structure. Dowels and close joints are often adopted to secure the respective frames also, and great strength is obtained in this way by joining the pairs together. But still a weakness is apparent; this transverse stiffening does little to help against the bending strains which we have called "hogging," or "sagging," to which every ship is exposed. Various plans have been devised. One of the most efficient is that which binds the frames together by diagonal pieces or "riders." Sir R. Seppings first introduced this mode into the Navy, since which it has been largely used. In "hogging," the upper part of a ship is, as we have seen, stretched, and the lower compressed, and Seppings endeavoured to reduce this tendency as much as possible by "diagonal braces or riders," which tied the ends of a ship to its middle in a direct way. To prevent undue compression he also introduced "fillings" to the timbers. For the diagonals, massive timbers placed at an angle of about 45°, their upper ends sloping towards the middle of the vessel, and their lower ends to the stem and stern, were bolted to the frames inside. Their heads thus met an angle amidships. Other pieces inclined in a contrary direction, called "trusses," were introduced, and longitudinal timbers bolted through both added to the rigidity of our wooden ships. In timber these additional strengthenings became a serious matter. They occupied considerable space, and, therefore, added greatly to the expense. Iron riders or diagonals have taken the place of the timber ones, and considerable gain, both in strength and economy, is attained. These iron diagonals are generally plate-iron bands from 4-in. to 6-in. wide, and about ½-in. to 1-in. in thickness, placed so that their lower ends should assist in tying up the lower portions of the frames where they get flat, and their upper ends meet at the midship section; in many cases they are fixed in the contrary way, though with much less advantage in resisting the hogging tensional strain. In some instances another set of diagonal riders are introduced, crossing the first at right angles, and this double bracing considerably helps to resist both kinds of bending strain. There is no doubt the midship part of a ship is that most exposed to these strains, and we think the idea of adopting the double system at this part, and the single riders at the ends, a good one, though we should prefer the duplicate system throughout. Sometimes these "riders" are fixed inside the frame timbers, and sometimes outside. The former plan is considered most convenient, and has been adopted by the Government, though we think it hardly gives so much direct aid as an outer bracing, where it forms a kind of stiffening skin within the plating, and has greater power in preventing buckling or flexure of the vessel; besides which under tensile strain, these iron bands press close to the timbers, and help by friction as well as by the bolts.

These diagonal bracing or "riders" are fixed either inside or outside the frame of the vessel, and considerably aid the resistance of the ship to the usual strains of "hogging" and "sagging." We now come to say a few words on the framing of iron ships—a subject beginning to enlist a large amount of attention, seeing that our latest improvement in scientific construction, and our most recently-constructed ironclads are still wanting in the ideal perfection attainable. The accident that befel the Vanguard has—in the popular mind at least—rather upset the claims of the cellular or water-tight compartment system of building, but without grounds. If the ram of the Iron Duke had run into an iron ship without the bulkheads, she must have gone down in considerably less than an hour after the collision. Imperfectly water-tight as the compartments were, and indifferently water-tight as they seemed to have been, the construction was such as to keep the vessel afloat for at least an hour, ample time to have tugged her to shallow water before sinking.

But to begin with the framing of common iron ships. This consists of transverse frames, like the framing of wood ships, only the frames are of "angle-iron" instead of timber. We need not here allude to the self-evident advantages over timber. These angle-irons can be obtained in complete lengths from gunwale to keel, saving the expense of scarfing, welding, and strapping. The outer or "frame angle-iron," as it is called, takes the outer plating to which it is riveted, while another angle-iron reversed, called the "reversed frame," is set back to back with the first, and also riveted together: thus the combination of the two constitutes a rib with two flanges in reverse directions. Across the keel, and forming the floor of the ship, is the "floor plate." These are plates made in two or more pieces strapped together, their ends being placed between the angle-irons to which they are bolted at a little height from the bottom of the ship. Ordinarily these "frames" are placed about 2 ft. apart, and being bound together at the lower part of the structure, by the floor-plates, great strength is attained. When a vessel takes ground on her keel she is exposed to severe bending strains on each side of the keel tending to break the floors; but the floor-plate joining the two sides of the ship forms a tie, and makes in fact the transverse section a hollow girder, thus combining rigidity with lightness. The greatest strain experienced would be at the middle, and hence the plates are made deepest near the keel, and are reduced to nothing at the bilges. Several forms of keel have been used; the simplest is of bar-iron, the lengths being welded or scarfed. In other cases, two bars with a deep centre plate which disconnects the floors are employed, the three thicknesses being riveted together to form a keel, and the floors being connected to the centre plate by angle-pieces. Another plan is the "flat plate" keel, or a continuation of the "garboard strake," or keel plating. Whatever plan is adopted it is evident the great object is to make a continuous rigid backbone as it were, to the ship, of which the stem and stern-posts form part. The stem and stern-posts are really continuations of the keel, being of bar-iron, though requiring some labour in forging. Iron ships do not require the "dead wood" of wooden ships. To give the backbone resistance additional means of strengthening are obtained, called "middle-line keelsons," "side keelsons," "bilge keels," &c. The keelsons are generally of I shape, though T shape or "box" shape are used. These side keelsons are best connected with the plating outside, and are fitted between the frames (intercostal). Bilge-keels are aften riveted on the outside of the bottom plating. Sometimes two or more keelsons are made between the keel and the bilge. In long ships these longitudinal strengtheners are of great value to resist bending and local strain. Transverse frames necessitate a line of rivet holes, making a weak section at the frames, and consequently any great bending strain would tax such a line of weakness. It is necessary, therefore, to have longitudinal ribs such as we have been considering. But another source of weakness in wood ships is to be found in the planking of the sides which form the webs of the structure. These are made up of pieces imperfectly joined and capable of sliding; but in iron vessels the strakes of outside plating are continuous, and riveted to each other at the edges, forming a continuous web, assisting greatly the framing and decks. Sometimes the frames, instead of being placed transversely, are placed at an angle of 45°; on one side sloping forward, and on the other aft. The deck beams also are framed diagonally, the different deck beams crossing each other. In the plating the plates are also made to butt in diagonal lines. The diagonal system so distributes the material as to prevent a bending strain taxing any transverse section or line of rivet holes. Thus the line of fracture is not in the shortest direction, and several diagonal frames help to resist the strain at any transverse section. Unfortunately, however, shipbuilders favour the "transverse system" as being less complicated and costly. They contend that transverse frames, strengthened by longitudinal pieces, may be made to give as much strength as the diagonal system with the same weight of material.

But there is another system of framing the "longitudinal" in which the advantages of both plans are combined. The keel is flat, supported by a keelson of plate with double angle-irons on both edges. The plating, formed of strakes, is secured to longitudinal girders of plate iron with angle-irons placed in reversed positions on each edge. The butts of plating and angle-irons "shift," and are strapped. The Great Eastern is constructed on this system, and Mr. Scott Russell is the promoter of this system, which has been largely adopted in armour-plated vessels. It is not necessary for each strake of plating to be secured to a longitudinal frame; in the Great Eastern every alternate strake is thus secured except near the keel, where each strake is supported by a frame. In this system the plating does not take the strains due to hogging and sagging of the vessel as in the transverse system, as the longitudinal frames act in the direction of their length. The transverse frames strengthen least of all longitudinally where the strains are more felt; but under the improved system the ribs resist with their maximum strength, and any line of rupture, section, or fracture, in a transverse direction becomes practically impossible, while the transverse frames invite fracture or buckling in the plating or skin between them. Above the lower decks the longitudinal frames are often dispensed with, the plating being laid on the deck. We may note here that it is not unusual to find in the old system the bottom plating of vessels much buckled by the compression due to hogging strains; especially has this been found with steel plating, which, being more resisting, is employed in thinner plates.

The bulkhead method of obtaining transverse strength must not be passed over. These bulkheads or compartments constitute rigid partitions in the hold, and are formed with plates stiffened with angle-iron at intervals. The intervals between the water-tight compartments are strengthened by the longitudinal frames or by some other mode of framing. Mr. Scott Russell has well applied this valuable means of affording transverse rigidity with extreme lightness, and other advantages to which we need hardly allude in giving a ship means of floating when the outer skin has been seriously ruptured by a collision or by striking upon rocks. The latter advantage, indeed, is undoubtedly the greatest when the bulkheads properly subdivide the length of the ship, and when due precautions are preserved to keep them water-tight. Between the compartments transverse frames or "partial bulkheads" are sometimes fixed about 12-ft. apart These consist of short lengths of plate fitted between the longitudinal frames and connected by angle-iron with them and the bottom plating. In some vessels, as the Great Eastern, additional security is given by an inner skin of plating riveted to the inside of the frames, thus forming a cellular water-tight double-bottom ship. For the bottoms of iron ships, especially when they are formed of thin steel plates, a cellular distribution of the material affords the greatest resistance to compressive strains, and acts in the capacity of a tubular girder or cellular flange, which we have already described.

Mr. Reed, late Chief Constructor in the Royal Navy, has considerably improved upon the longitudinal system already described, adding to the safety and strength of a ship as well as saving weight of material and workmanship. The longitudinals are made deeper, so as to give access for cleaning and painting, and to regulate the "trim" of the vessel by letting in water between the bottoms for the purpose of ballast. The transverse frames are placed about 4-ft. apart, and have angle-irons, the reverse angle-iron being made continuous, while that to which the outer plating is riveted is fitted between the longitudinals. A continuous tie is thus secured by the inner angle-iron. To connect these outer and inner angle-irons or frames, bracket-plates are used with short angle-iron ends. This plan is known as the "bracket-frame" system, and is well adapted for iron-clads. It gives a double water-tight bottom with increased transverse strength. The longitudinals, or most of them, are fastened to the stem, and assist in giving the bow rigidity for the "ram" system of attack. This system only applies to the unarmoured part of the hull. Above this, or from about 5-ft. below floating level, the main framing is of transverse ribs.

ON THE QUALITIES OF SHIPS.

MERCHANT SHIPS.—Merchant ships are designed to carry goods from one place to another across the sea. Their size as well as their qualities must therefore be different, partly according to the merchandise they are to carry, and partly according to the nature of the seas in which they are to navigate; but generally a merchant vessel should have the following qualities:—

1. To sail well, especially by the wind, in order to be able to beat off a coast where it may be embayed, and also to come about well in a hollow sea.

2. To be able to sail with a small quantity of ballast.

3. To work with a crew small in number in proportion to its cargo.

The two first qualities can be obtained by giving the ship great length and breadth in proportion to its displacement and a small depth to the bilge in proportion to the breadth; but such a vessel requires large sails and heavy anchors, and consequently a great complement of men. The third quality can only be obtained by making the ship short, narrow, and deep, in proportion to its displacement; but a ship constructed in this manner, may not be able to move through the water with the necessary velocity, neither close-hauled nor with the wind abaft the beam. It may, therefore, happen to come into danger, and perhaps be lost for want of good sailing qualities, although it will carry a great cargo in proportion to the expense for the crew and for wear and tear.

As the third condition is in a complete opposition to the two first conditions, and as the ship *must* be able to sail with the necessary degree of safety across the seas, it follows that a merchant vessel, to be as profitable as possible to its owner, cannot possess the very best sailing qualities obtainable.

The vessel that will carry the heaviest cargo with the least expense, and still with a sufficient degree of safety from one place to another, will answer the purpose best. Theoretically to determine the best proportion between the displacement, length, breadth, and depth, is therefore impossible; but the proportions adopted after a practice of more than a couple of thousand years will be the best guide. It is found that the length of sailing vessels varies between three and four times the breadth; in later times, in order to gain a greater velocity, the length has been made as much as six times the breadth, but it is doubtful if these very long ships will answer except under particular circumstances, and if not, this proportion will not be generally adopted. The depth from the load water-line to the rabbat of the keel varies between one-half and one-third of the breadth. The larger the ships are, the longer and deeper they are in proportion to the breadth; and this is theoretically correct, though it is certain enough that practice alone has given these proportions to the ships. A proportion between length, breadth, and depth, that in all cases will be better than every other proportion is not to be found, and we also learn from practice that two ships of the same displacement may be very different in regard to the proportions between length, breadth, and depth, and still both be good sea-boats and swift-sailing vessels. The proportions between these three chief dimensions are therefore not of very great consequence when they are not carried to extremes, and it may only be alleged as deduced from practice:—

1. That the length ought to be greater in proportion to the breadth in large than in small vessels.

2. That the breadth may be between one-third and one-fourth of the length, and in some particular cases as little as one-sixth of the length.

3. And the depth from the load water-line to the rabbat of the keel from one-half of the breadth in the largest ships to one-third of the breadth in the smallest.

Of more consequence than these proportions, when they are not carried to extremes, is more or less fulness of bottom, having more influence on the ship's qualities, both in regard to sailing qualities and tonnage in proportion to the number of the crew.

If very good sailing qualities are required the ship's bottom must be sharp, with fine lines forward and aft. In this case the hull will be heavy in proportion to the weight it will be able to carry; and to get the displacement that is necessary for the intended cargo, the ship must be given a greater length, breadth, and depth than needed in case of the bottom being more full or flat, whereby she, of course, will be more expensive to build, will require larger sails and anchors, consequently also a greater complement of men, which altogether are circumstances unfavourable to the owner. If the bottom is made more flat or fuller towards the extremities she will, with less length, breadth, and depth, carry the same load, she will be less expensive to build, require a smaller number of men to work her, and be more profitable to her owner; but she will lose something of her good sailing qualities. By making her too full she may lose so much of her sailing qualities that she will be unable to sail with safety except in fine weather. It will therefore generally be advantageous for the owner to be satisfied with a good deal less than the best sailing qualities that may be obtained by a vessel of a given displacement.

In determining the fulness of the bottom, the nature of the seas in which the ship is to navigate, as well as the nature of the cargo that she generally is to carry, must be taken into consideration; for a ship designed to carry merchandise of great value that will bear a heavy freight, or perishable goods, as, for instance, fruit, may with advantage be made sharper than a vessel designed to carry goods of small value in proportion to weight and volume, such as, for instance, timber and deal. Likewise vessels that often shall have to cruise against the trade-winds must have better sailing qualities than are necessary for other ships, that are not commonly exposed to encounter such impediments.

To determine the fulness of the ship's body, we must resort to experince, although this does not give any other rules than that the larger ships may be made more full than the small ones designed for the same trade, and still retain sufficiently good sailing qualities. But as no fixed rules can be given for determining the quantity that influences the fulness of the ship's bottom, it must be left entirely to the constructor's own experience and judgment to determine this quantity.

Merchant ships provided with steam power may be made longer and narrower than sailing vessels, because their manœuvres do not in narrow seas depend on the sails, and because they by this measure will obtain greater speed for the steam power alone.

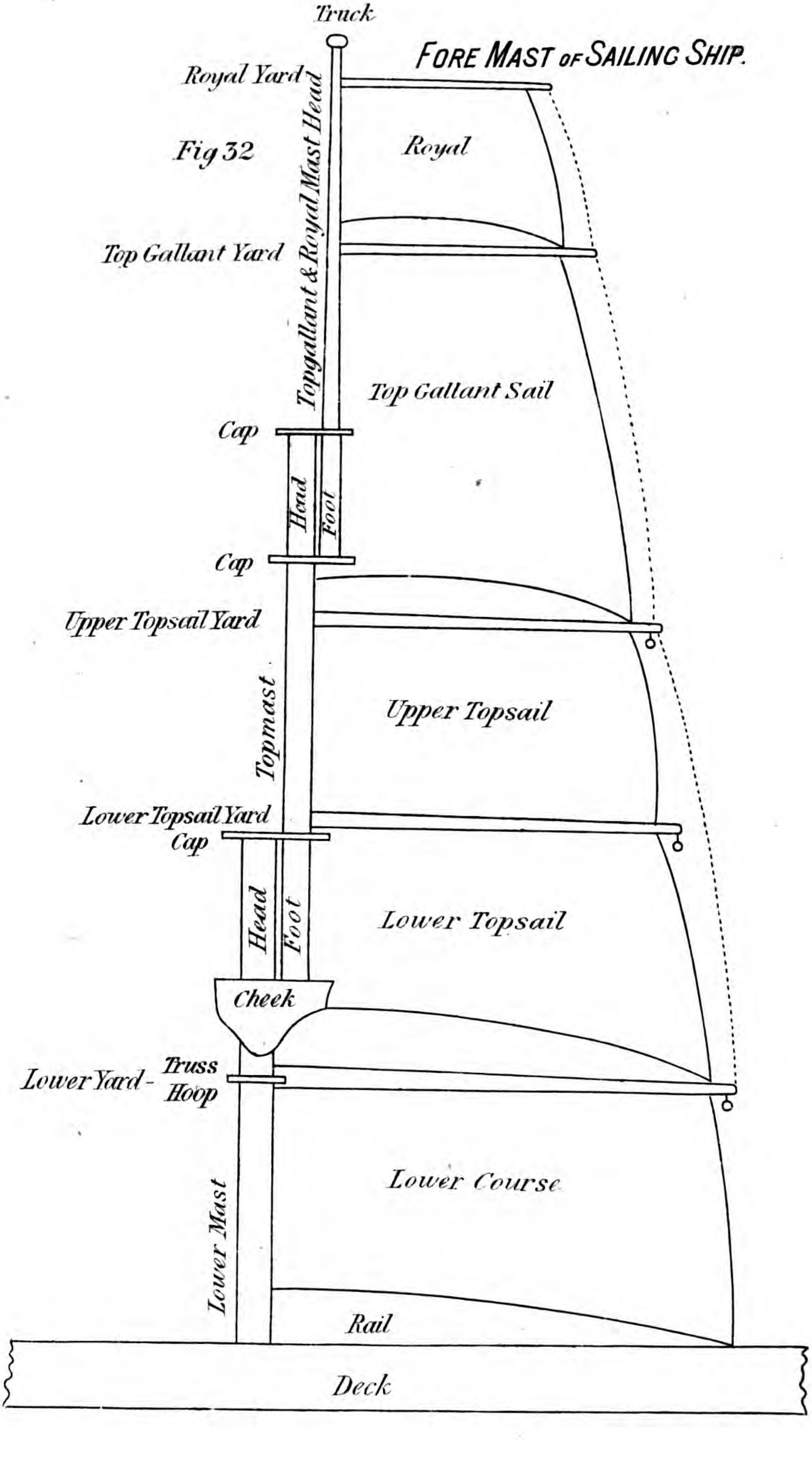
Steam-ships intended chiefly for passengers are generally built still more longer in proportion to their breadth, but for sea-going vessels it is probably most advantageous never to let the length exceed eight times the breadth.

SECTION III.

IRON MAST-MAKING.

Whilst there are books treating on Iron Shipbuilding, Boiler-making, Bridge Girder Building, &c., I have not yet come across a book or author on Iron Mast and Yard making. We have standard authors, such as the late Professor Rankine, who give proportions and ratios on this subject. The Underwriters' Rules also do this, but they are mainly suggestive; it may be that the subject is unimportant, or in a state of transition from good to better. However, when I see so many of our young men in the trade anxious, as they ought to be, to "get their hand in," as they call it, and as iron mast-making has now assumed such an important position in the trade, to them at least, I will endeavour to lay down for their guidance a system of practical construction. We will examine some of the methods usually employed in laying off and making Iron Masts and Yards. Some may say, why make so much of it? a mast is a mast. True! so is a tree; some are straight, some are crooked, some are twisted, some are shapeless—if the term may be used as applied to a tree. We have seen cases where the term could be fitly applied to iron masts, and it is to obviate this (we hope without presumption) that we thus enter so fully into it.

It is the ordinary practice to lay down blocks and planks the whole length of the mast on one side of the shipyard, then to take the plates and square the ends—very often with a T square. Shear and plane the ends, then lay them on the planks to a straight centre of plate line; the next thing is to put on a shear batten on both sides to the sizes given. Having set the shear battens fair to please the eye, then scrieve along


FORE MAST OF SAILING SHIP.
Fig 32
Truck
Royal Yard
Topgallant & Royal Mast Head
Royal
Top Gallant Yard
Top Gallant Sail
Cap
Head
Foot
Cap
Upper Topsail Yard
Upper Topsail
Topmast
Lower Topsail Yard
Cap
Head
Foot
Lower Topsail
Cheek
Truss
Lower Yard -
Hoop
Lower Course
Lower Mast
Rail
Deck

the outer side of the battens, after which put on the template, and mark off the rivet holes, being fortunate, if uncovered by a roof, you can accomplish the marking off without being annoyed or the work spoiled through bad weather. The template used here is a continuous one, 30 or 40 feet in length, without uniformity as to length of plate, the holes at the butt ends coming on promiscuously, some half, some whole holes, just at the end of one plate, leaving a blank in the plate next to it.

We have seen, with the exception of this fault in the holes at the butts some first-class jobs that were every way fair and good. But look at the risk of bad weather and waste of time and labour in laying out, the material passing twice through hands when once would do the work at least equally well. We must not forget that ships of the largest size are built without the aid of a mould loft, how much more so a mast without laying out. Take also the case of a marine boiler, where the several parts are laid off in small compass, but when put together make one uniform whole. Another method practised by some yards on the Clyde is to line off the whole mast on the mould loft floor, then make frame templates of wood for every plate in the job, when after marking the holes and numbering they are transferred to the plater, whose duty then is to mark off these templates, punch, bend, and bolt together, when, if the work is good, all right; but if there is anything wrong, what then? Who is to blame? or who is the mast-maker? Certainly not the plater, who, in this instance, is little better than a mere labourer, let his skill be what it may. This method speaks for itself, and without speaking of the waste in templates, or the want of or absence of a mast-maker, reminds one of the adage of "Too many cooks," &c.

We will now proceed a step further on; and, first, we will set up a model to keep in our mind's eye, paying strict attention to proportions, symmetry, and shape. Fig. 32 represents foremast of sailing ship. Although our work is to construct, the designs being furnished to our hands, it facilitates our work to know the design, if possible the whole design, and the intentions of the designer, chief among which are that the work shall be executed according to his plans; and when we consider the multifarious plans, all subject to, but coinciding with, one general plan of the whole in the building of a ship, we shall see the necessity for thoroughly understanding each in its place, and what is required.

There are few things in the handiwork of man more beautiful than a well-modelled, well-built ship; and as the masting forms an important feature, second to no other, we must study to have form and fairness, avoiding twist and irregularities, as one blemish in any part mars the whole.

In Fig. 33 we have a representation of a lower mast, and foot of topmast, with fid hole. It shows the cap cheek and truss hoop at the decks. We have the doubling shown, extending below and above both decks 18 inches or 2 feet, to wedge at both decks.

We are also shown in Fig. 34 a bowsprit and jib-boom combined. It shows the doubling at knightheads and staying hoops, built of three plates in circumference, with bars the length of the bowsprit on each course of plates; jib-boom built of two plates, flush jointed, and socketed into bowsprit at bob-stay hoop, 2 feet; diaphragm plate at doubling, 12 feet in length.

In Fig. 35 we are shown a lower yard, with truss bow and hoops, sling hoop, and doubling.

In Fig. 36 we have a portion of a plan of a mast of three plates in circumference; the plan is as simple as may be, and we have taken a three-plate barrel as a middle course between a two and four-plate barrel—the method is the same in either case; in a mast of this size with three plates we would have to put in bars, but we will deal with that in the proportions. It

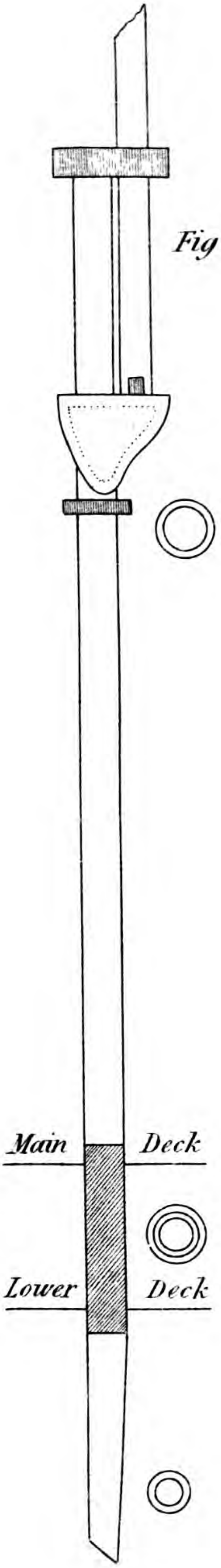


Fig 33

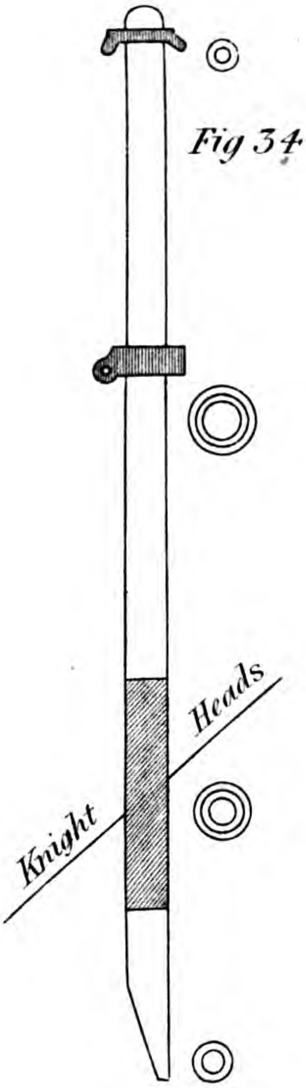


Fig 34

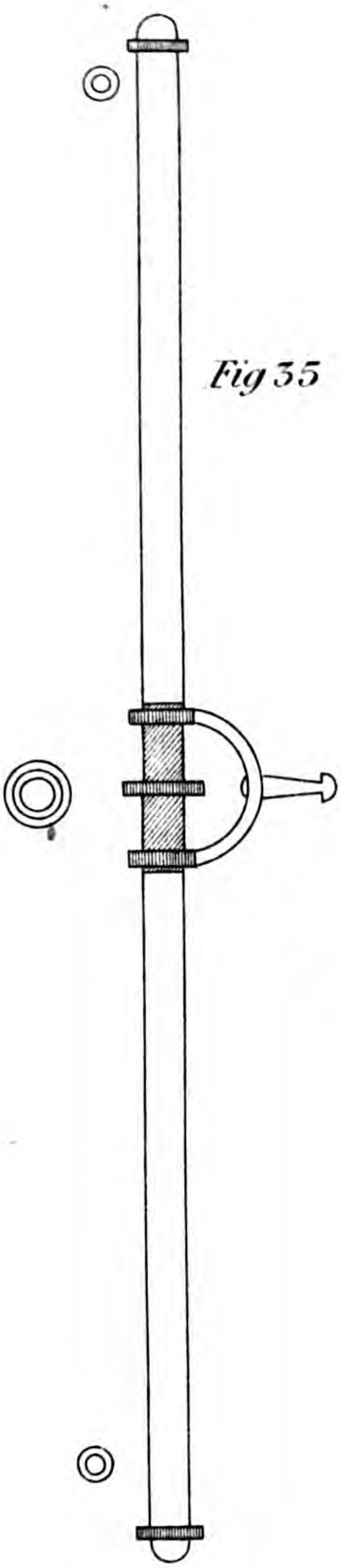
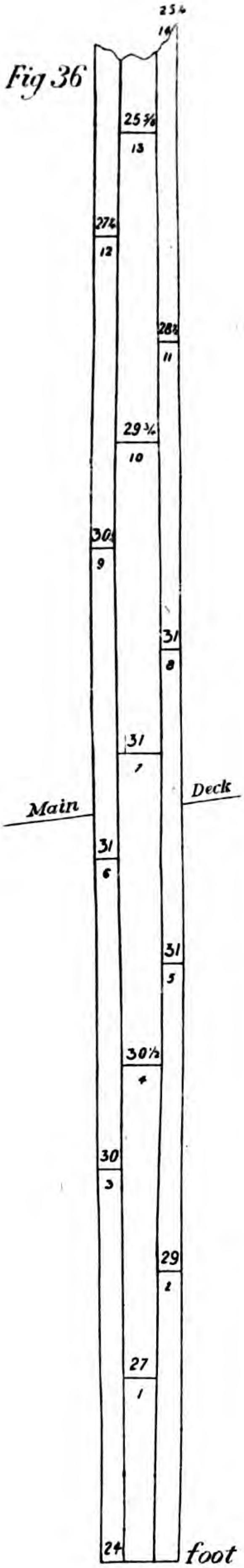
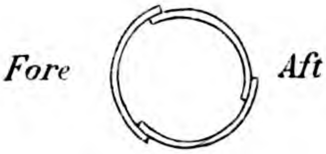


Fig 35

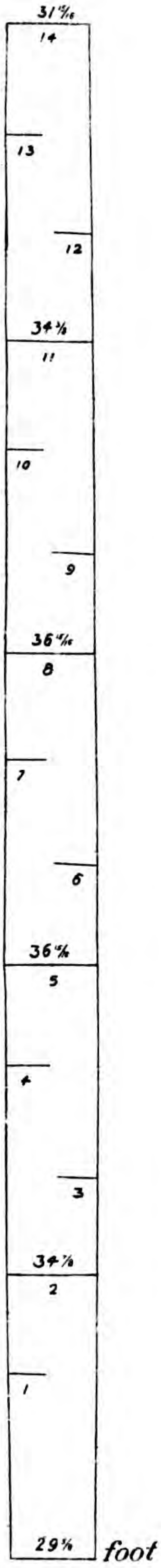
Fig 36





Section

Fig 37



will be seen that we have started at the foot of the plan and numbered our butts upwards, as 1, 2, 3, 4, &c., we also have our diameters at the different butts marked on deck lines, hounds, &c.; we stretch the plan on a board, and look along the lines to see if there is any irregularity, when, if satisfied, take fine-pointed compasses and measure the plan to scale at every butt. We then note and table in a book particulars—such as the numbers of the butts, their diameters and circumferences, allowing for lap, the mark and numbers of the plate, position of doubling cheeks, &c.

In Fig. 37 we have five plates developed, with their sizes at their own butts, and numbered to correspond with Fig. 36; we also have the positions of the other plate butts as they fit on this course, with their numbers; but this figure is of no use, except just to show how the other two courses fit in with it. We will dispense with it altogether, and keep by Fig. 36, as a plan. We here copy a table of mizzen-mast with three-plate barrel, given size 28 inches, plate lengths 11 feet 6½ inches:—

TABLE OF SIZES.

MIZZEN-MAST.—MARK ON PLATE, M M.

No. of Plate.	No. of Butt.	Size.	Size.	No. of Butt.	No of Plate.	No. of Butt.	Size.	Size.	No. of Butt.	No. of Plate.	No. of Butt.	Size.	Size.	No. of Butt
1	heel	$12\frac{3}{4}$	$13\frac{1}{2}$	1	16	heel	$12\frac{3}{4}$	$14\frac{5}{16}$	2	17	heel	$12\frac{3}{4}$	$15\frac{1}{16}$	3
2	1	$13\frac{1}{2}$	$15\frac{13}{16}$	4	15	2	$14\frac{5}{16}$	$16\frac{1}{2}$	5*	18	3	$15\frac{1}{16}$	$16\frac{3}{4}$	6
3	4	$15\frac{13}{16}$	$16\frac{7}{8}$	7	14	5*	$16\frac{1}{2}$	$16\frac{7}{8}$	8	19	6	$16\frac{3}{4}$	$16\frac{7}{8}$	9
4	7	$16\frac{7}{8}$	$16\frac{7}{8}$	10	13	8	$16\frac{7}{8}$	$16\frac{7}{8}$	11	20	9	$16\frac{7}{8}$	$16\frac{11}{16}$	12
5	10	$16\frac{7}{8}$	$16\frac{3}{8}$	13	12	11	$16\frac{7}{8}$	$15\frac{7}{8}$	14	21	12	$16\frac{11}{16}$	$15\frac{3}{8}$	15
6	13	$16\frac{3}{8}$	$14\frac{13}{16}$	16	11	14	$15\frac{7}{8}$	$14\frac{1}{4}$	17	22	15	$15\frac{3}{8}$	$13\frac{11}{16}$	18†
7	16	$14\frac{13}{16}$	$13\frac{1}{8}$	19	10	17	$14\frac{1}{4}$	$12\frac{3}{8}$	20	23	18†	$13\frac{11}{16}$	$11\frac{3}{4}$	Cap
8	19	$13\frac{1}{8}$	$11\frac{3}{4}$	Cap	9	20	$12\frac{3}{8}$	$11\frac{3}{4}$	Cap					
OUTSIDE COURSE.					INSIDE COURSE.					IN AND OUT COURSE.				

* Doubling Plate centre 5″ above No. 5 Butt, 11 feet doubling.

† Cheeks 9″ below No. 18 Butt, space between Cheeks finished 18″, Head of Mast 12′ 6″, Length of Mast 80′ 3″ × 28″.

TABLE OF DIAMETERS.

MIZZEN-MAST.

No. of Butt.	Diameter.	No. of Butt.	Diameter.	No. of Butt.	Diameter.	No. of Butt.	Diameter.
Heel.	20″		28″		27½		21⅞
	22½		28		27		20⅝
	23		28		26⅛		19½
	24½		28		25⅛	Cap.	18
	26		28		24		
	27¼		27¾		23		

Ship's Burthen, 1,600 Tons.

The preceding table gives size on each side of the middle plate line, and includes lap. It will be seen that we have the dimensions at all the butts; we also have the numbers of each plate as they are ordered from the maker and marked on the plan.

We have next a table of diameters at all the butts, with the different diameters circumscribed in the case of a two-plate barrel. We can measure across, but with three or more plates in the round we require to draw them on a board, and make gauges, two of which will do for all, with altering for the different plates as required.

In case (as sometimes happens) the marks or numbers on the plates get rubbed out in their transit from the maker to the shipyard, we shall have a copy of the plate order and table it according as they are marked on the plan, and as we lay off and mark each plate for punching we can, to prevent duplicate, also mark them off on the table.

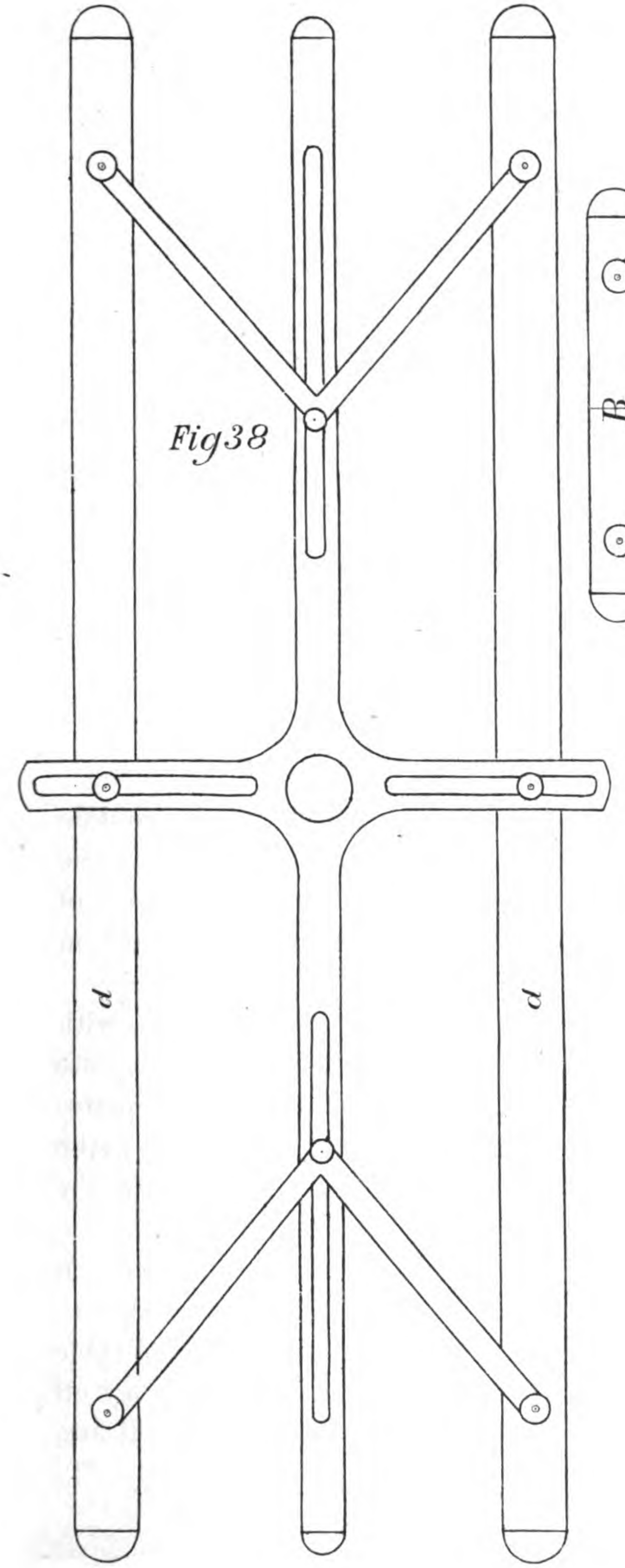


Fig 38

Fig 40

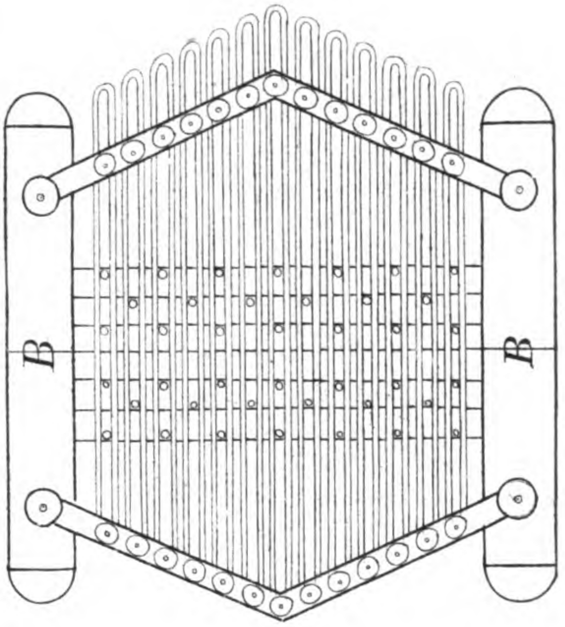
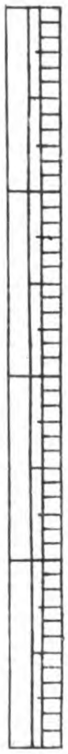


Fig 39



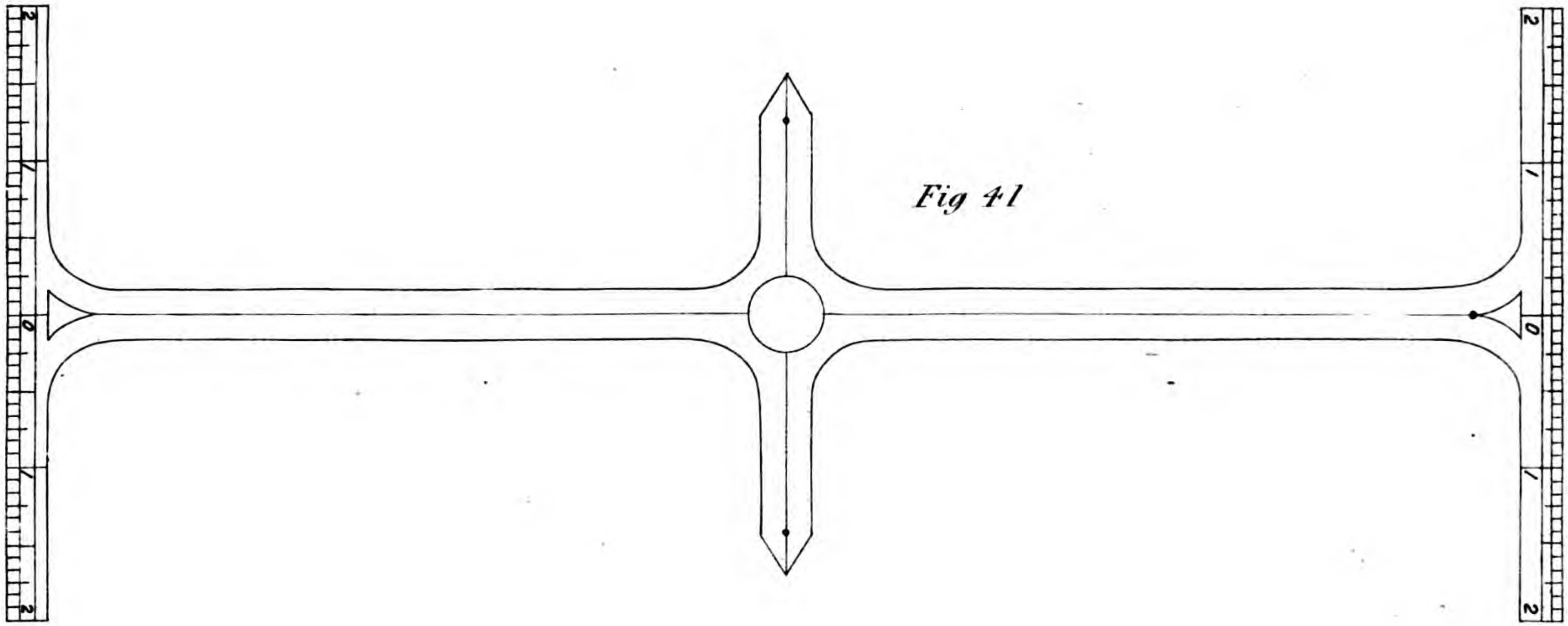


Fig 41

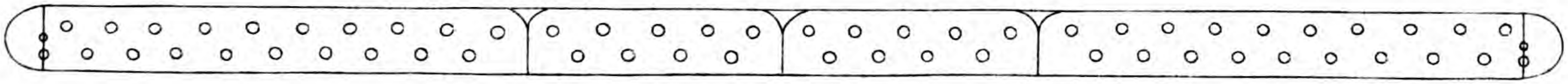


Fig 42

MAST PLATES (MARKED M M).

No.	Length	Breadth		Thick	No.	Length	Breadth		Thick	No.	Length	Breadth		Thick
1	3·7	26″	27½	$\frac{6}{16}$	16	7·6	26″	29	$\frac{6}{16}$	17	11·3	26	30½	$\frac{6}{16}$
2	11·6½	27½	31¾	"	15	11·6½	29	33	$\frac{7}{16}$	18	11·6½	30½	33¾	$\frac{7}{16}$
3	"	31¾	34¼	$\frac{7}{16}$	14	"	33	35	"	19	"	33¾	35	"
4	"	34¼	34½	"	13	"	35	34¼	"	20	"	35	34	"
5	"	34½	33	"	12	"	34¼	32	$\frac{6}{16}$	21	"	34	31	$\frac{6}{16}$
6	"	33	30	$\frac{6}{16}$	11	"	32	29	"	22	"	31	28	"
7	"	30	26¾	"	10	"	29	25¼	"	23	11·10	28	23¾	"
8	8·0	26¾	23¾	"	9	4·2	25¼	25¾	"	...	...	...	...	...

Straps, 2. 2′ 10″, 9¾ × $\frac{8}{16}$; 3. 2′ 6″; 6. 2′ 8″ 14¼; 2. 2′ 11″ $\frac{7}{16}$; 6, 2′ 5″; 3. 2′ 9″. Butts doubly riveted below and treble-riveted above deck. 3 Doubling Plates, 11·0 × 27 × $\frac{7}{16}$.

Having got our sizes tabled and ready for reference, we will next consider our template. In Fig. 38 we have moveable template to work to any size, and always to the square line, the laths, *a a*, are reversible, being fastened at the connecting links with thimble screws to one of the holes. The laths can be holed to any form of riveting. In Fig. 39 we have a rule indicating right and left, one for each end of the template, to fasten on at centre line.

In Fig. 40 we have an expansive template for marking the holes at plate butts, the laths B B are reversible, same as Fig. 38, and can be holed to suit plate ends, also for marking straps, if an inside strap, contract, if for an outside strap, expand, the template, keeping in view that there is a difference in or out of fully three times the thickness of the iron in a half circumference. In Fig. 41 we have another form of template; here we have a gauge the exact length of the plate. Rule marked at each end to the right and left of the centre line, we can thus mark on the size required at once, also centre-punch the middle and centre lines, as shown at small holes. We make a strong point in having each plate square to its own centre, as thereby we may expect a fair and straight mast; also paying attention that the butts are well and correctly planed, as it is evident the 1-16th of a foot wrong on one side of the plate will in a 10-foot plate throw it off the centre plate line 10-16ths. Having lined off the plate and marked on alternate butts, we next lay on template lath, Fig. 42, taking care to have the right side up, as it will require to be turned over, or over end, as we mark an inside or outside lap, that is if for zigzag riveting, but if for chain riveting, either side up or either end up or down makes no difference, if the holes are equally pitched and equally divided at the butts.

It is plain that when the plates are laid out in courses, butted off a centre plate line, that there is more iron in length on the outside or edge of the plate line than there can be on the centre of plate line.

That is suppose we stretch a batten along the outside curve line and then mark the length, then apply the batten along the centre line, it will at once be seen that there is a considerable difference in length between the centre and outside line, with the result that when the plates are bent up to their diameters and put together, we have the butts open in proportion to mast taper, as shown in Fig. 43. Here we have two plates A B, finished, squared off the back of the plate; to get our butt close we must lift up the small end of the plate, then what becomes of the edge or lap line? In Fig. 44 we will suppose C a mast plate, the difference in length of centre and edge of plate lines are fully shown, as also at dotted lines.

As a mast is more or less in shape conical, we would require, in order to get our butts square to centre of cone or centre of mast line, to plane them after they are bent, when the plate in this case would be as shown in lines at the butt; this would require a circular planing machine, like a face chuck or large turning lathe, but as we are mostly confined to a horizontal plane, we adopt the expedient of marking

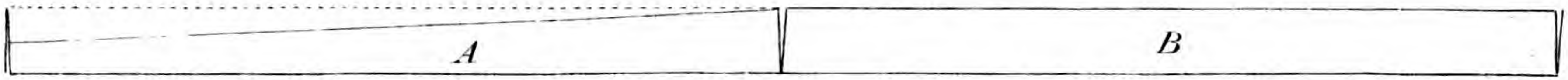
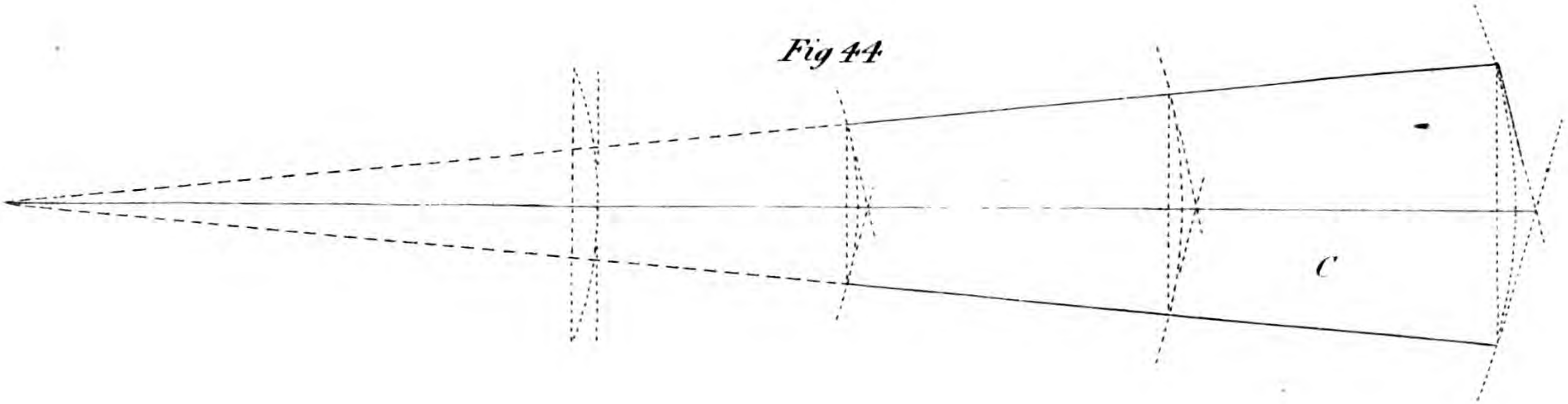


Fig 43

Fig 44



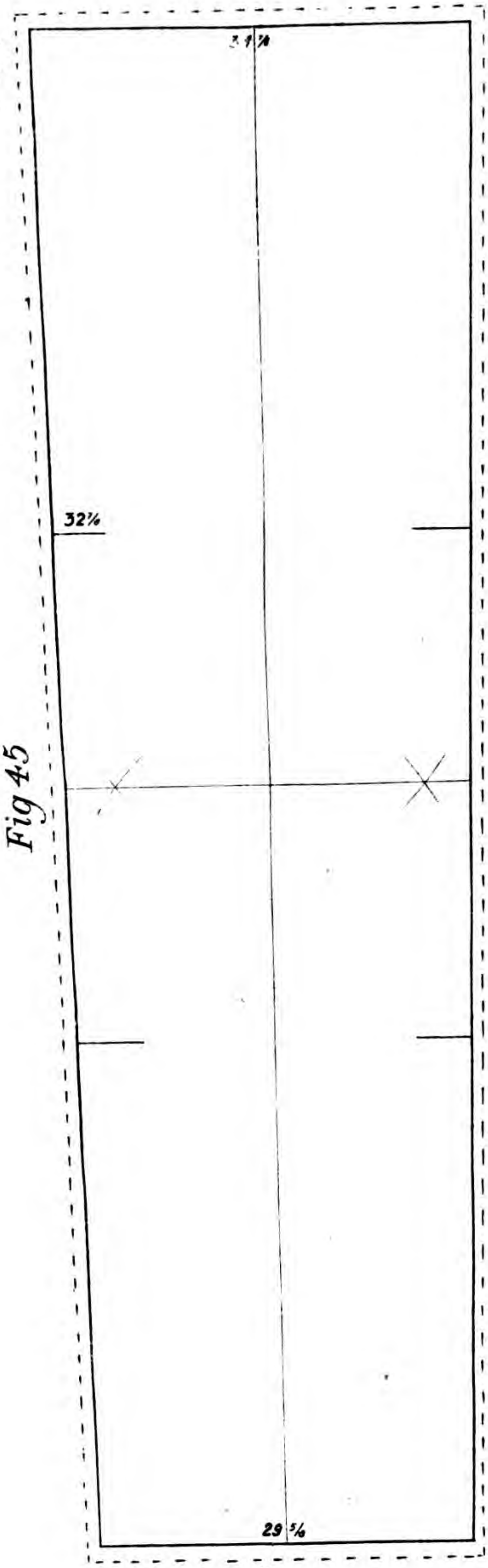


Fig 45

Nº 2 BUTT ROUNDED UP TO LENGTH OF EDGE LINE TAKING FOOT-LINE FOR A BASE.

each plate separately and independent of each other. By this method, besides other advantages (to be noticed further on), we can make our plates all one length, and secure close butts and straight lines.

We have taken Fig. 45 representing the first as shown on mast plan, Fig. 36, page 92; we have also lined it off, as shown in the dotted lines, outside show rough plate, the black lines show the correct size of the plate and positions of butts, with butt No. 2 rounded up; we manage this by taking our length of edge line and keeping our narrow end straight across, take three or four measuring spots on it, this gives the correct length across the wide end of the plate.

We make it a rule to round up the wide end of the plate only, taking the narrow end for a base; parallel plates require no round up at the butts. The red lines at centre show manner of squaring plate with compasses.

In Fig. 46 we have shown a plate marked off; its position in the mast is at the deck line, as shown on mast plan; we have marked it as for an outside course, with template lath as represented in Fig. 38, page 94.

We also have doubling plate holes marked off; in this case the doubling plate will be inside, the width of which will be the same as inside strap. That is taking the distance between centre line holes and edge line holes at $12\frac{1}{7}$ inches; we would require to contract the same lines on the doubling plate (it being $\frac{1}{2}$-an-inch thick) to $11\frac{13}{16}$ inches, with $1\frac{3}{8}$ inch for edge of plate. If for an outside doubling plate, we require to expand same lines of holes to $12\frac{11}{16}$ inches, with edge of plate over, we find it thus —

As there is a difference in a $\frac{1}{2}$-inch hoop out or in of $3\frac{1}{8}$-inches, we put this into 32nds :—

$3\frac{1}{8} = 100\frac{1}{32}$nds,
divide 100 by 6 = $16\frac{2}{3}$.

We divide by 6, taking from centre line to centre of lap as $\frac{1}{6}$, and as this is fully 16 inches, we thus have a difference of

$\frac{1}{32}$-of-an-inch for each inch in width of doubling plate; for $12\frac{1}{4}''$ we take $\frac{7}{16}$ nearly.

We can now easily go on and mark off and punch all the plates in the mast, observing to punch the inside lap edge from the outside or faying surface of the iron.

This is simple with the plate length template; we only require to mark a hole at each end, punch or reverse it when having punched the inner faying surfaces and sheared the plate; then turn the plate, apply the template mark and punch, we thus get smooth faying surfaces, the value of which, as compared to the rough punched surface, require no remarks here.

In Fig. 47 we have three plates laid out according to their position on the mast, showing the rivet holes for the fastening on cheeks. It is not absolutely necessary that we should lay them out thus as taking the exact height from a butt, and, having it in our table of sizes, we can mark them in in the first marking off by putting on the lines and applying same template and taking alternate holes.

We must mark off sling plate as shown at centre. Note, it makes a good job to double the mast in the way of the cheeks from 24″ above to 12″ below cheek plate. We may now assume that all our mast plates are punched. We must now, before going to the bending machine, shape the mast foot so that, when bent to size and but together, we will have it to the rake of mast with a level foot ready to step.

We have in Fig. 48 the three bottom plates laid out, we get the radical or curve lines 5, 5 and A C from the rivet holes as shown; then dividing from the centre line to centre of lap into four equal spaces on each side, and putting in lines, as shown at 1, 2, 3, 4, 5, we next carry the curve line from A B to A O, also E B to E O. We now start at the base O or cutting line, on No. 1; one-half below cutting line on No. 2 line; the cutting line at No. 3, or centre line; one-half above the cutting line on No. 4 line; and the cutting line at No. 5 line, we thus

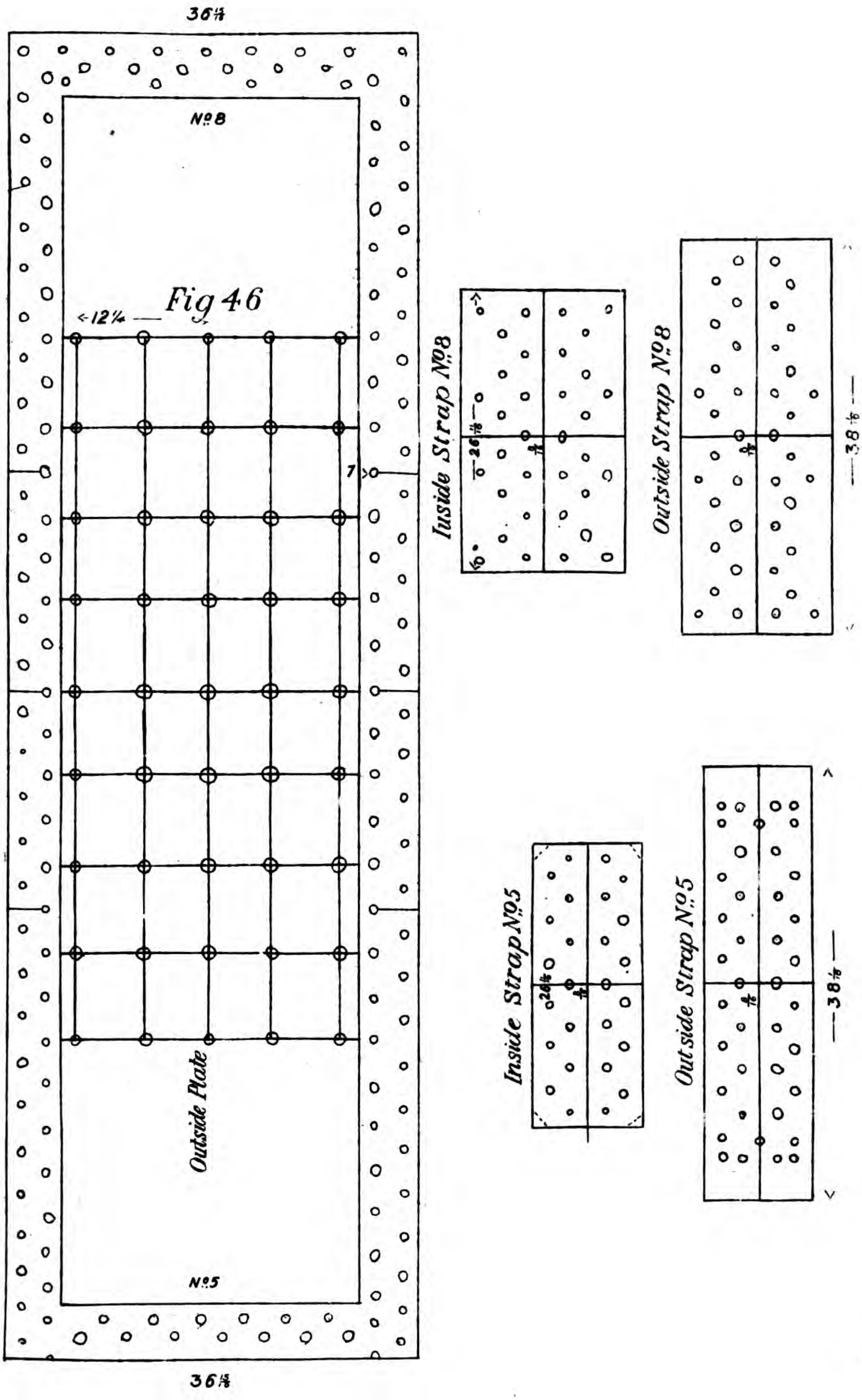

36⅝
No. 8
12¼
7
Outside Plate
No. 5
36⅝
Inside Strap No. 8
26⅝
Outside Strap No. 8
38⅝
Inside Strap No. 5
26⅝
Outside Strap No. 5
38⅝

Fig 46

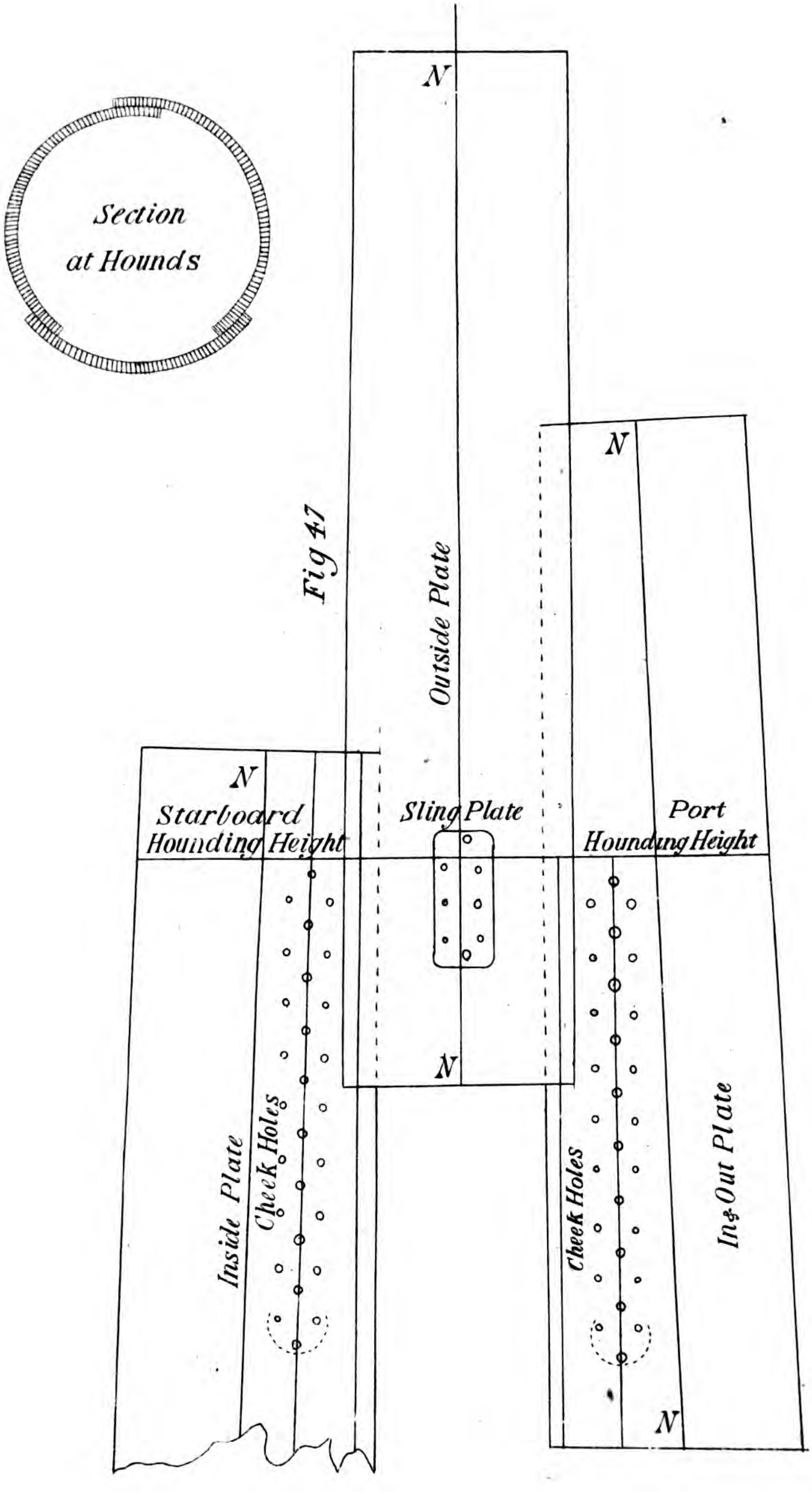

Section at Hounds
N
Outside Plate
N
Starboard Hounding Height
Sling Plate
Port Hounding Height
N
Inside Plate
Cheek Holes
N
Cheek Holes
In & Out Plate
N

Fig 47

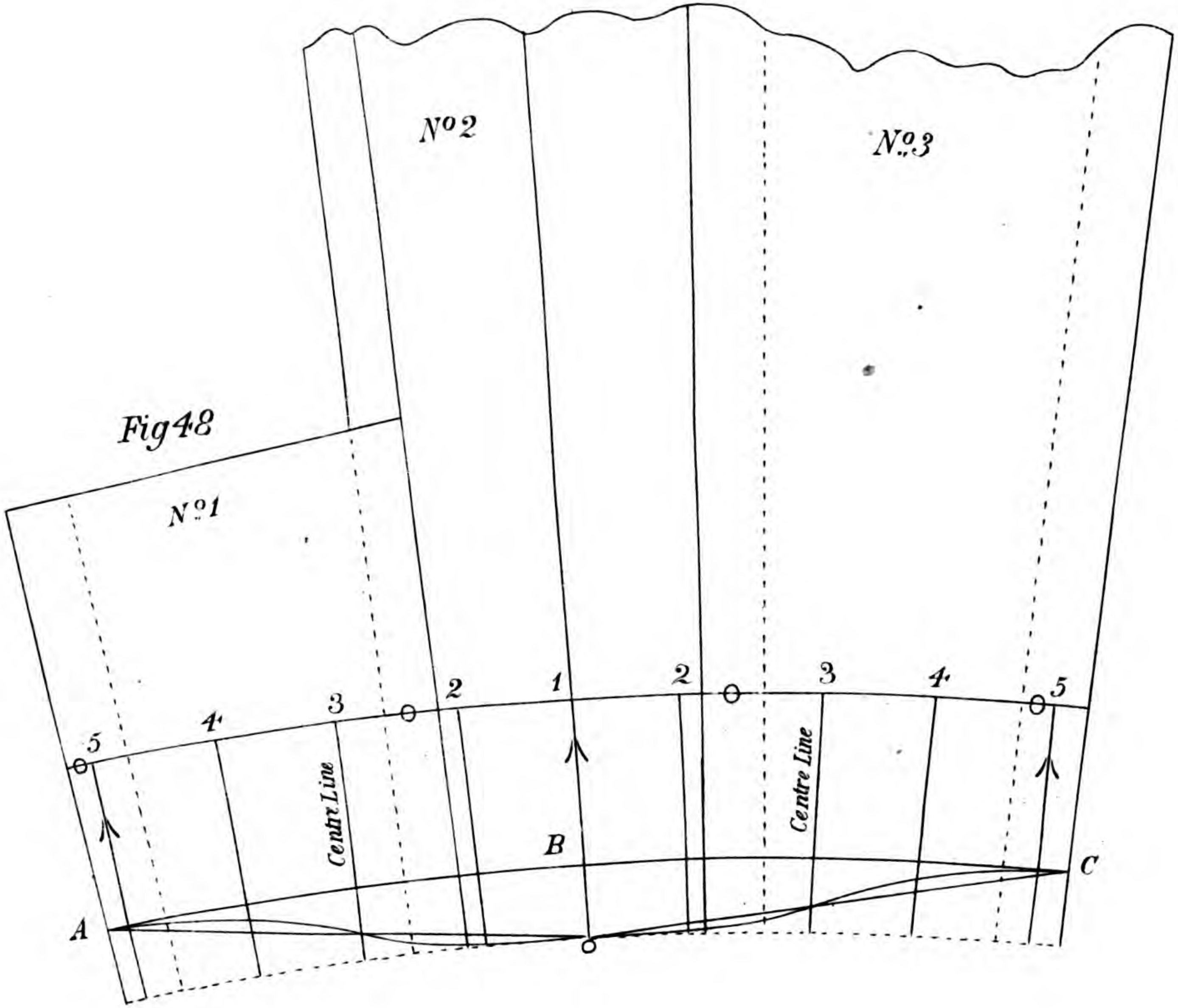


Fig 48

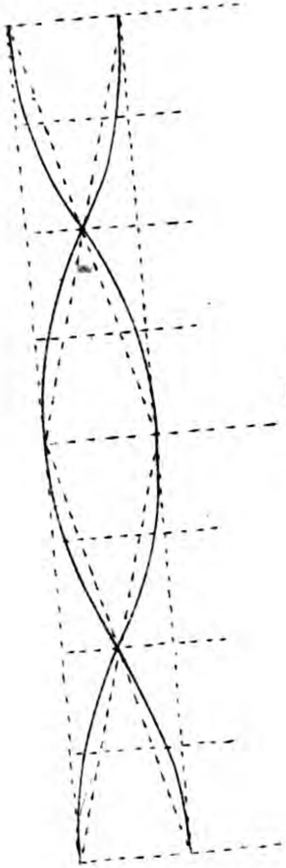


Fig 49

Fig 50

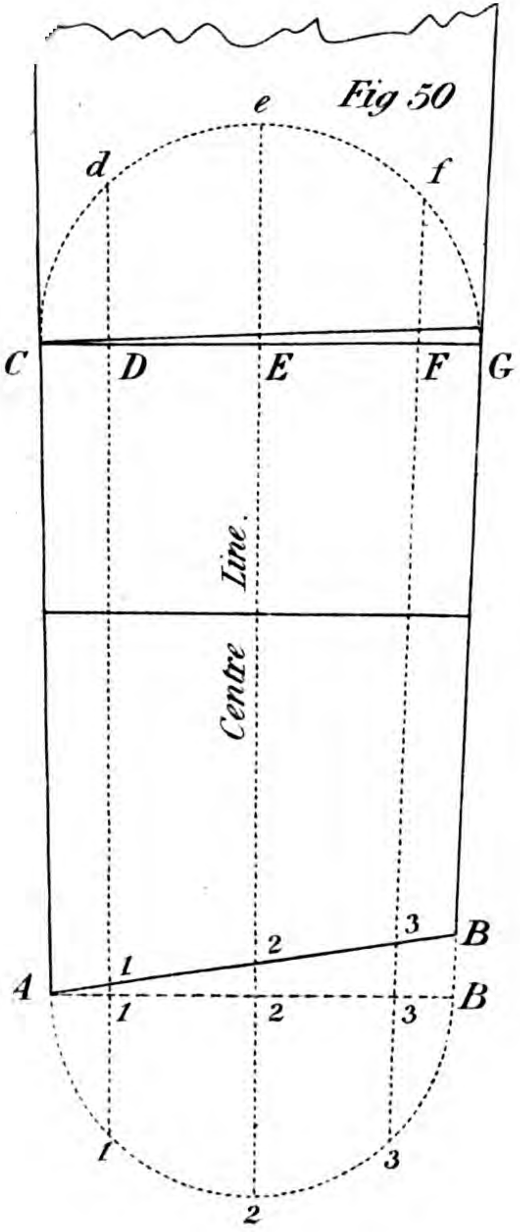
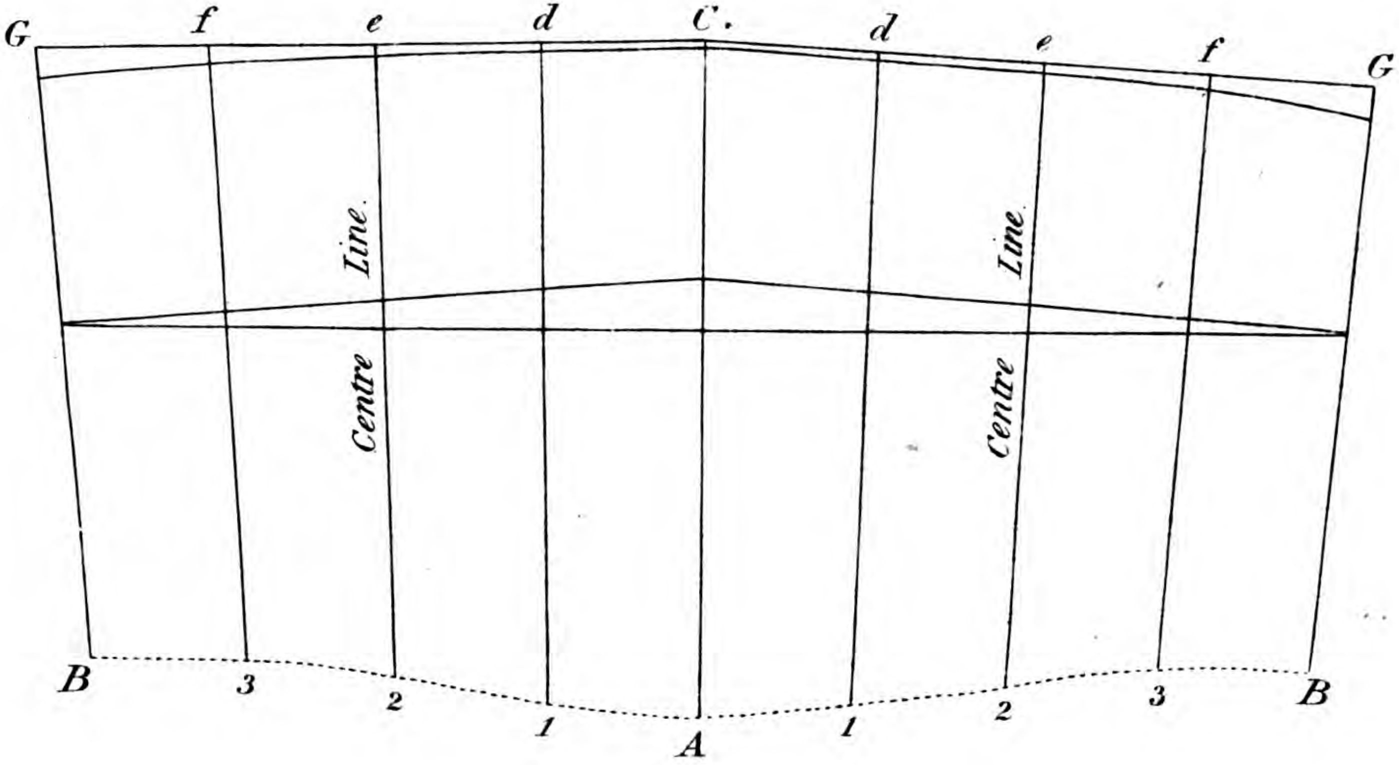

e
d
f
C
D
E
F
G
Line.
Centre
1
2
3
B
A
1
2
3
B
1
3
2

Fig 51


G
f
e
d
C.
d
e
f
G
Line.
Centre
Line.
Centre
B
3
2
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A
1
2
3
B

get the curves A, O, C, drawn in cut off, to which the plates when bent off to shape, will form a level step with a rake of 2″ to the foot.

In Fig. 49 we have rough sketch of curving out bevelled tube ends on parallel tubes; it shows the points at cutting and half over and half under cutting lines out and in.

The following is a method of cutting out mast steps. First set off a portion of the bottom of the mast as shown in Fig. 50, cut off to rake as shown at A B, then set up half circumferences at bottom, and anywhere above rake at top; divide the bottom as shown at 1, 2, 3 line in parallel to centre line till you meet line A B in the half circumference; do the same at top, D, E, F line, in parallel to centre line, till you meet the line C G or half circumference, then carry the lines from 1 to D, from 2 to E, and from 3 to F, the figure is complete.

We next put on the lines at the divisions, as shown in Fig. 51. The best method to get a curve line here for a base is to square off the centre lines to get points, then draw in the base curve line at bottom, then transfer the measurements in Fig. 50 at 1, 2, 3 B to the corresponding lines in Fig. 51, we thus get the points or cutting lines to form with a thin batten the finished curves, as shown at B, A, B.

Note.—The foot of a mast should be doubled at least 1 foot in length.

We will now lay off and cut out the step at bowsprit heel (Fig. 52, shape of step). We have here the heel shown with a half cut, and to rake 1 in 3 a common ratio. In Fig. 53 we have the deck line cutting through the side of the tube or cone at B 4, and the vertical line cutting through the end of the tube or trustrum of the cone at M 4, by setting up the half circumference, as shown here, and dividing into equal spaces on the half circumference, as shown at 1, 2, 3, &c. We carry these divisions in parallel lines to the centre or diametrical lines, next carry the lines from one diametrical line to the other; we thus get the lines as if we had carried them from the apex to the base of the cone.

In Fig. 54 we have the tube or trustrated cone developed by transferring lines and measurements to corresponding lines. This could be developed by projection or by hinging the plane, but, as shown, is much the simplest and quite correct.

A common method of gammoning the bowsprit at knightheads is by the erection of a tube connected to two small bulkheads through which the bowsprit penetrates to its position. This tube is for the purpose of wedging up the bowsprit at the knightheads.

The inboard and outboard bevel or rake of this wedging tube sometimes vary according to circumstances.

We have in Fig. 55 a figure of a tube with varying bevels into half circumferences, set up and divided at the lines and points shown.

In Fig 56 we have the tube developed both by projection and measuring spots. The lines 1, 2, 3, are butt or centre of rivet lines. We require to bend this round square to the ends, the lines being parallel to the roll.

In Fig. 57 we get the elliptical shape of one of the ends. Our next business will be to lay off the round tops and mast cheeks. In Fig. 58 we have a portion of the mast laid down with a centre line; from this we get a square line at top, and from the square line at top we get our rake per foot of distance from centre line; we can now make a mould to shape, marking on it a centre line, and the different line of rake for other mast. We must observe that the more we diverge from a straight line in our camber on the fore side of the cheek, the more we reduce the strength to bear the structure above, and increase the tendency to buckle.

In Fig. 59 we have a cheek plate with fastening holes marked off. We punch these holes only before the plate is bent to shape, marking them with the ordinary mast template, and taking alternate holes, leaving the holes for angle and

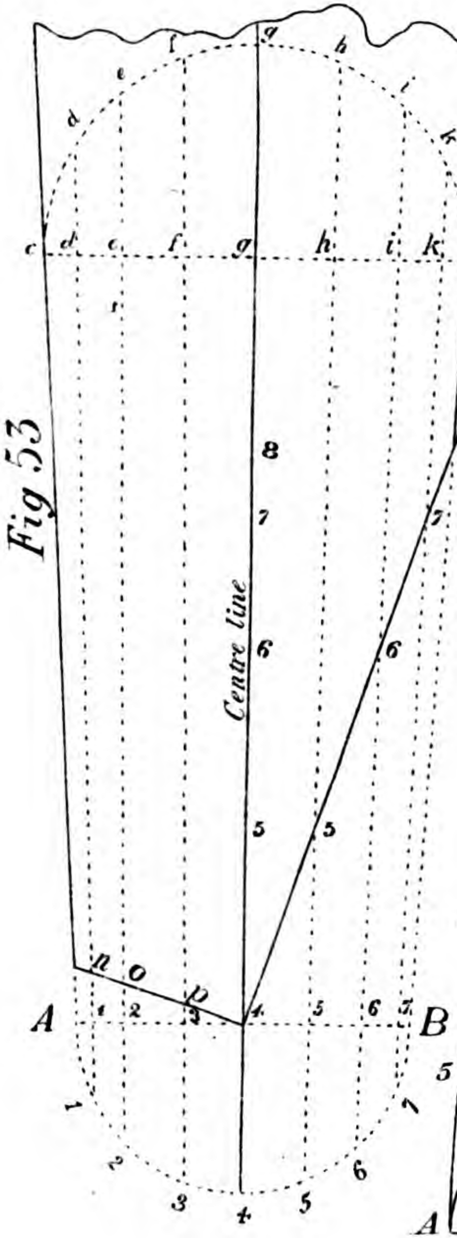


Fig 53

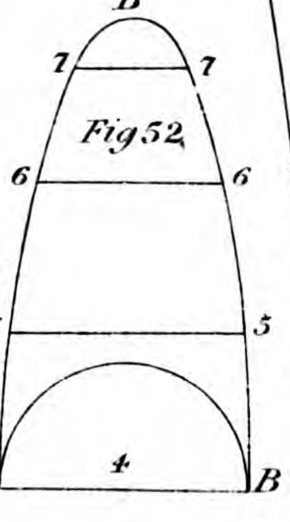


Fig 52

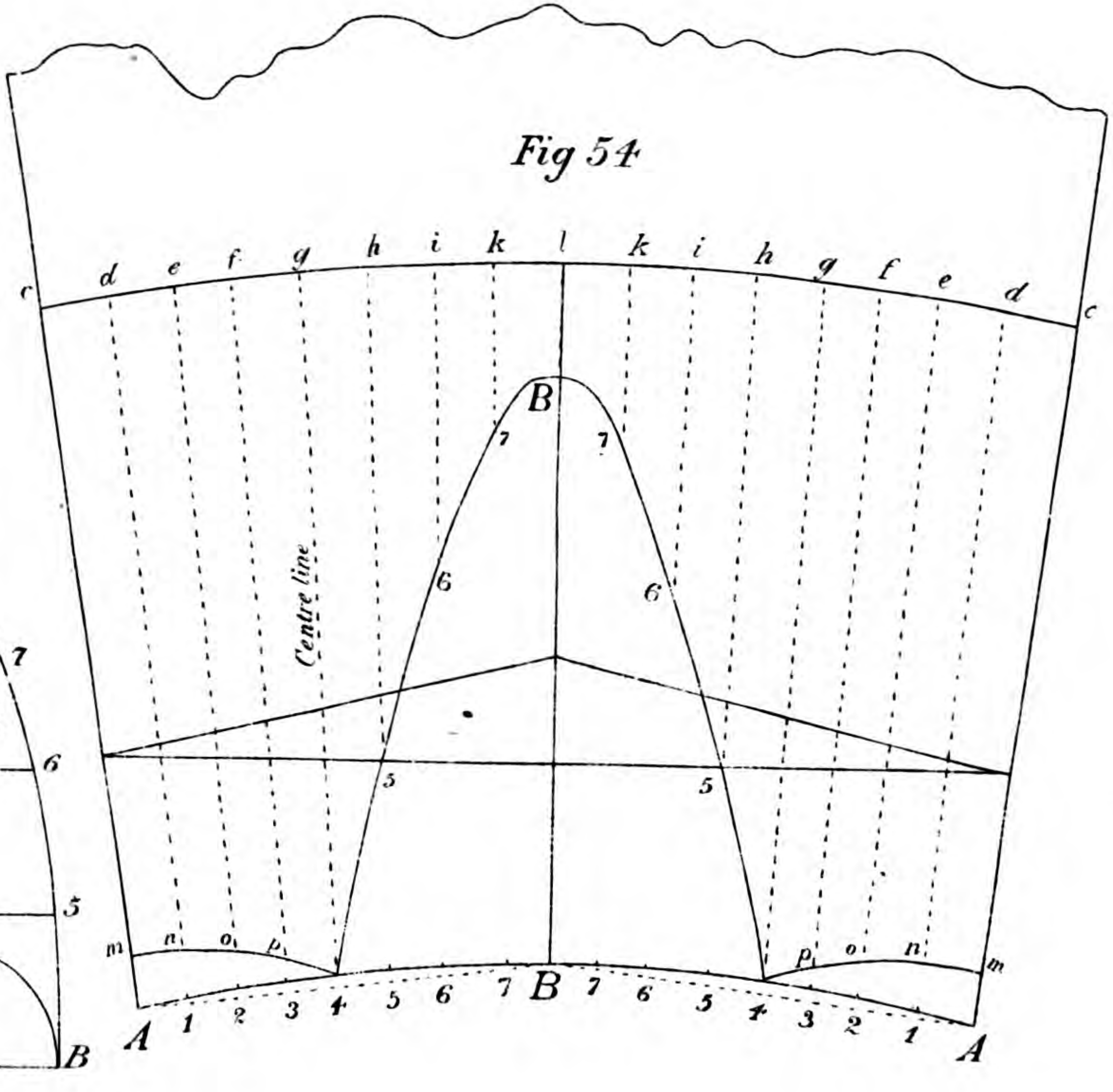


Fig 54

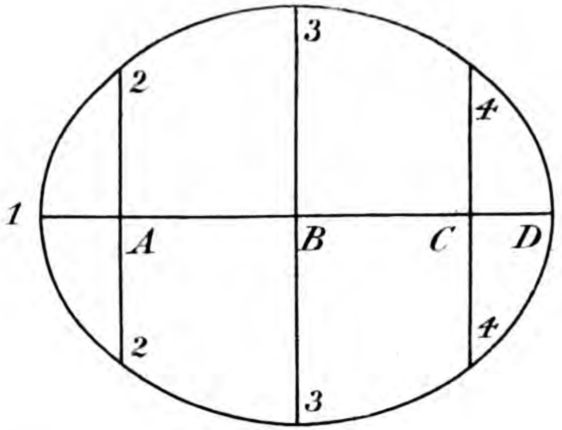


Fig 57

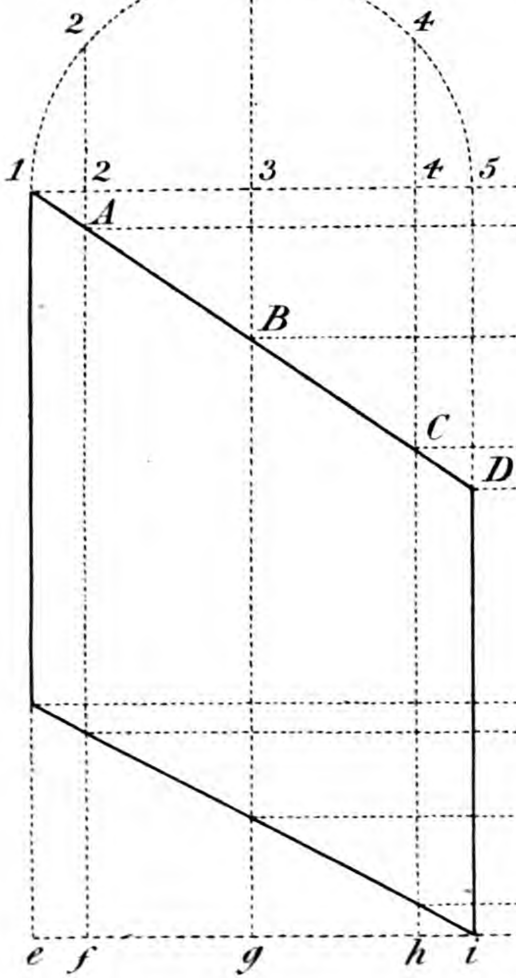


Fig 55

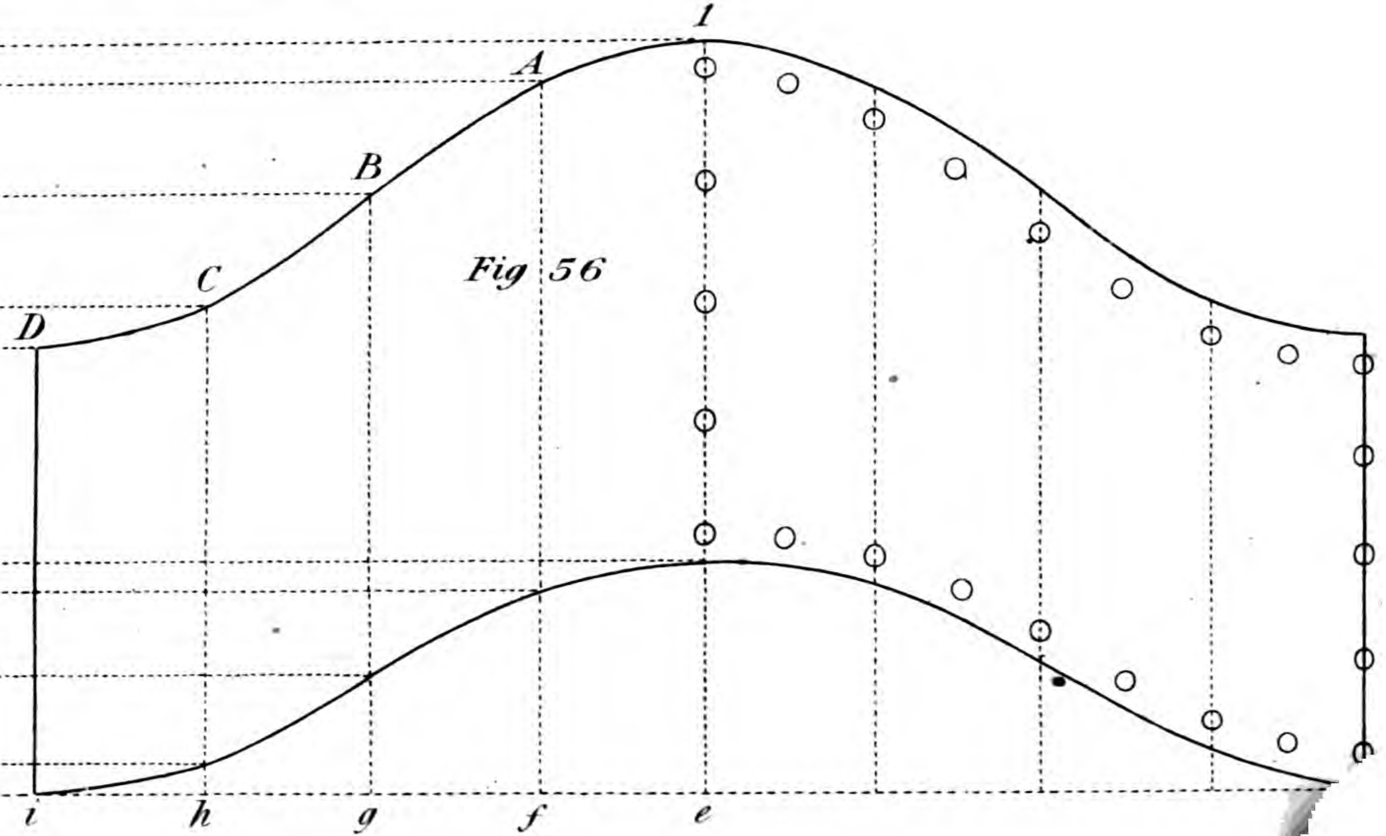


Fig 56

coping bars out until the cheeks are forge to shape, in case of rent or fracture at the holes. In marking off the cheeks as shown, we must allow here for the outside hoop. In marking off the cheek holes in the mast plates, let us suppose the outside lines of holes, 4 inches from the centre line, and the mast at the hounds, 24⅜ inches diameter, for it must be observed that, in laying off the mast, we have not subtracted the thickness of the iron. The given size at hounds is 24 inches, so that we have once the thickness of the iron in addition, which makes 24⅜ inches in diameter.

The cheeks are ¾-inch thick. We will now see how much to expand our line of holes.

In the mast plates, as shown, we have 75½ inches.

In the mast bent up and finished, we have on the outside circumference 76⅝ inches. We have thus expanded 1⅛ inch, or three times ¾ inch the thickness of the iron.

Diameter of mast 24⅜ inches; add thickness of cheeks ¾″=

25⅛ inches.	Circumference of cheeks	79 in.
3⅐	Expansion of mast	1⅛″
3⅝		80⅛
75⅜	In the straight plates	75½
79 inches.		4⅝ inches.

We have thus a difference of 4⅝ inches more in the cheeks flat than in the mast flat in the circumference. This is very nearly $\frac{1}{16}$ per inch in the circumference, and we would require $\frac{4}{16}$, or 4¼ inches between centre and outside line of holes.

There is another thing in connection with mast cheeks that we will do well to take notice of here; that is, if cut to rake to a level or load line. In Admiralty ships the mast head caps and cheeks, whatever the rake of the mast, are cut to and rake with a load line. In merchant ships the mast-head caps are put on square to the middle or centre of the mast line. This has the effect that, when the mast is shipped in position, the eye is deceived, and the fore side of the top appears drooping in consequence of the cap slanting, and the greater the rake of mast the more it appears. In the case of ordinary merchant ships' masts we keep 1 inch at the fore point at cheek higher than the given rake, if the given rake be from ½-inch to 1 inch per foot. If the rake be greater, and the cap square to the mast, we keep the cheek proportionately higher at the fore point to please the eye.

We will now lay off the round-top. In Fig. 60 we have shown the different requirements in making a round-top except that we have not marked the holes for the boarding, which can easily be done when we know the breadth of the boards, or whether it may be iron-grated. The holes, as shown, are all required for bolt holes in the fairleaders, bolsters, and boarding, and round-top, and cheek connection. The largest holes are for eye-bolts, for sheets, clews, &c. Before bending our round-top bars, we punch ½-inch holes every 12 inches on the outer rim of bar for half round wood coping. Also, if necessary, punch holes for futtock stay clamps, bearing in mind that we are going to bend one-half of an angle hoop, the expansion on the back of which will be noticed in angle hoops.

After the tops are welded or fastened at the corners, mark off and punch all the holes, as shown, also the boarding holes. It will be seen that we have marked the holes for connecting and fastening the tops to the mast cheeks angles. We next construct a template, as shown at Fig. 61, with a counterpart of the connecting bolt-holes. This serves to mark the holes in the mast cheeks angles, and much easier applied than the round-top or the round top-mould. When the cheeks are fitted on to the mast, apply the template in position, and fair from centre line, then mark off the holes.

In fitting the cheek plates on the mast, care must be taken to have them fair and without twist, and to see that we have them corresponding to and parallel with a centre of keelson

Fig 58

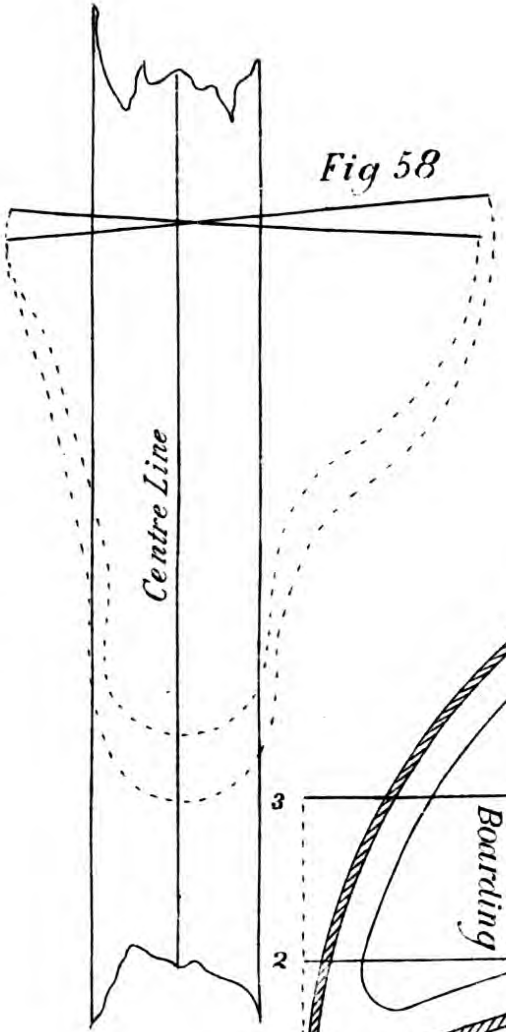


Fig 59

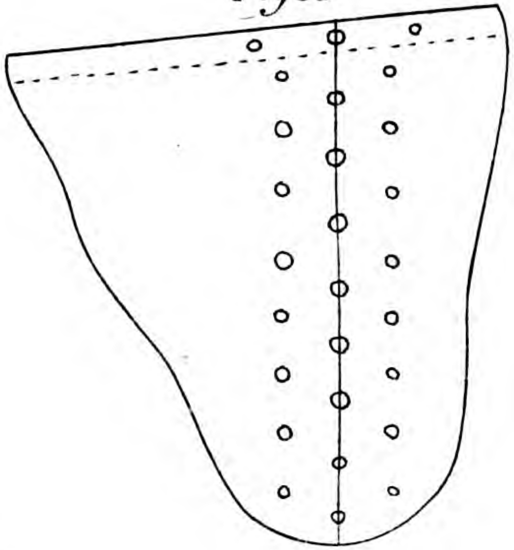


Fig 60

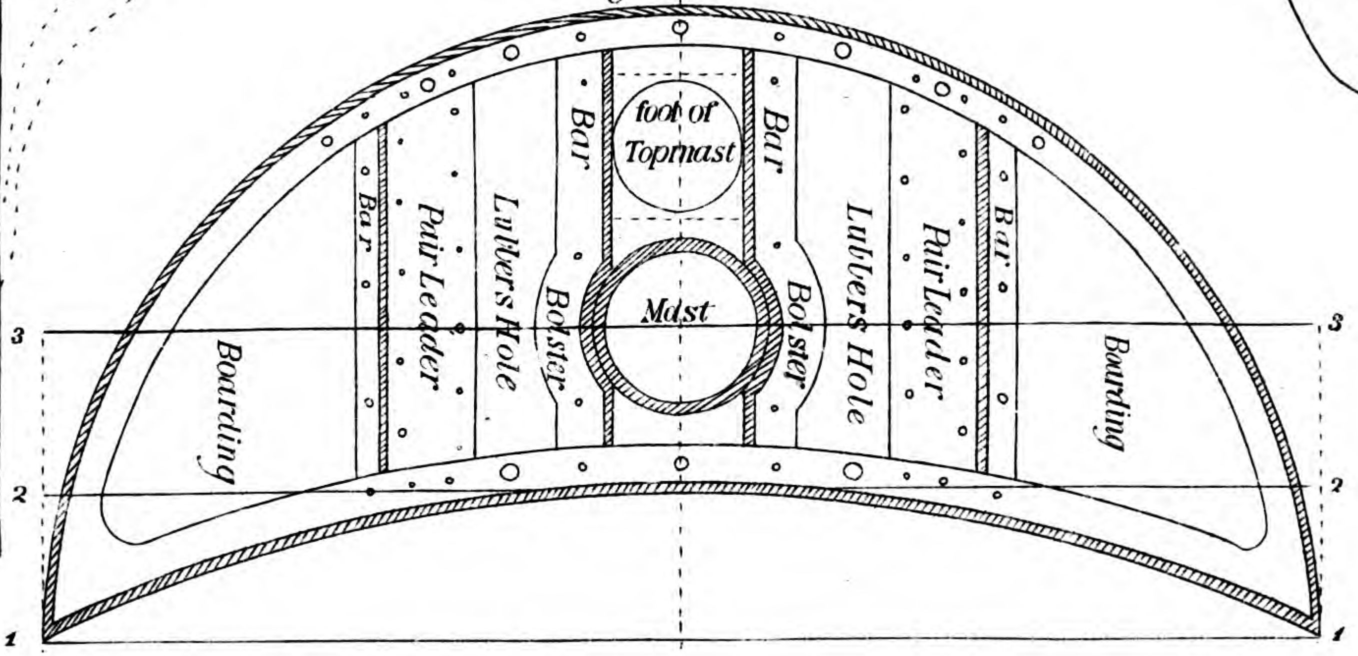
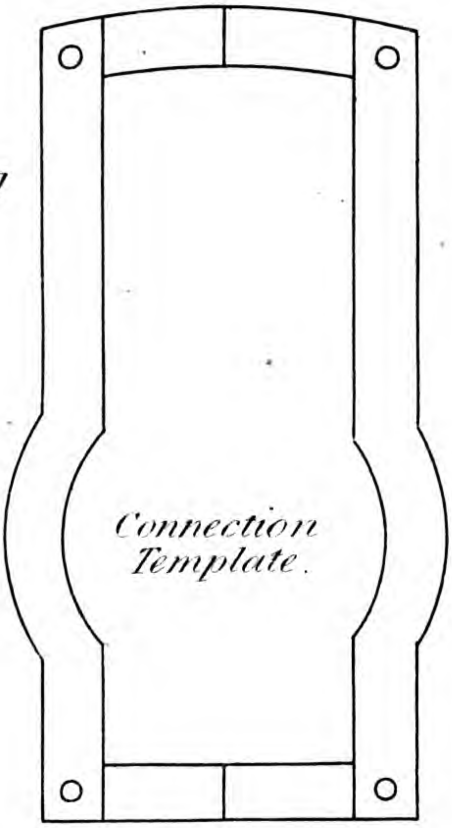


Fig 61



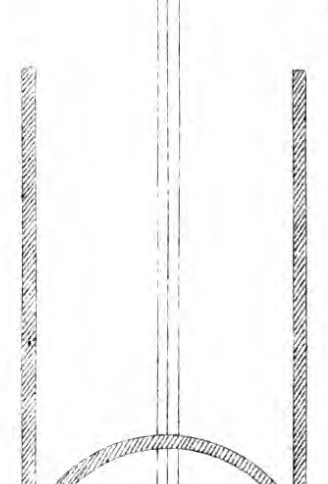


Fig 62

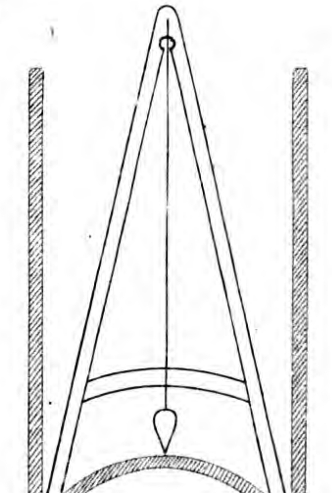


Fig 63

line and as the mast may not be perfectly round on account of laps, &c., and as a very little at the bend of the cheeks will put us a good way off at the points, we adopt the following method to get fairness :—

The mast foot is very often cut to step over a double angle iron, enclosed by an angle wedging hoop. The double angle in the aperture so cut out we place firmly a piece of wood, perfectly straight, this forms a keelson line. In the case of a plain mast foot, we jam a piece of wood into the mast, and set up our keelson line, or batten on the wood so fixed.

We then turn the mast until we get the batten in a vertical position, as shown at Fig. 62. We next put a centre line on the mast at the hounds; the next operation is to bolt on the cheeks, which we do hot, and inclining inwards at the points, the screwing up will bring them out. Apply the plumb rule as shown at Fig. 63 ; when having got them equi-distant at both sides, top and bottom, put on the bars. Also fix on temporary bands at the connection holes, that they may not shift in riveting.

The cheeks being now connected to the mast, we will next examine the fittings required for the part of the mast embraced by the term hounding,* also yards, slings, hoops, &c.

We have in Fig. 64 a sketch of that part of a mast, showing the principal fittings we have omitted to mark on the bracing eye plates, as their positions are different on each mast. The sketch explains itself, but we would draw attention to the hounding hoop, introduced here for the purpose of strength. It is reverse to, and forms with cheek handle a double reverse angle, which forms a cravat round the mast, and assists the cheeks in sustaining the superincumbent weight. Another advantage is, that we get double strength to bear the rigging

---

* The term hounding, as applied here, means the cheeks and the connections.

bolsters, which in the case of single iron, yield and come down with the lurching of the ship and strain of the rigging. We also get an angle bar attached, as shown, for the foot of the topmast to heel upon. The wedging bar at the foot of the topmast is fastened with bolts, but removable, to allow of the mast moving up or down when wanted.

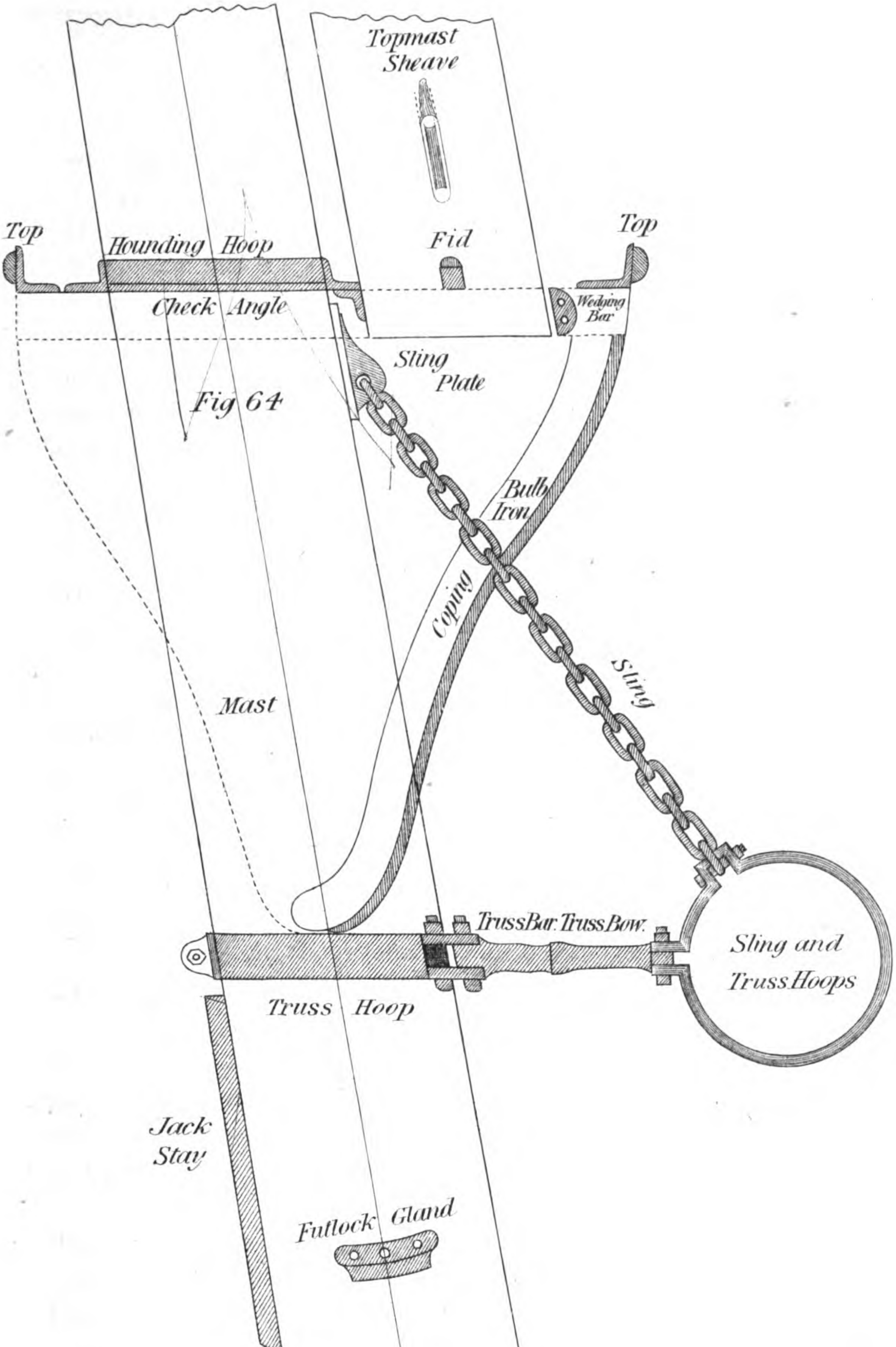
The coping on the fore-side of the cheek sometimes consists of an angle bar, with the outer flanged reduced sometimes of half-round iron, but we prefer to put on a piece of bulb iron, as, besides the additional strength, we think it looks fully better, the holes being fairly spaced zigzag, and cup-riveted on the outside.

It will be worth our while here to look at the several methods that are generally common in the hounding angle bars that have to do duty in connection with the cheek plates in carrying the weight of the masts above itself, as well as also the weight of all the upper rigging. We must likewise bear in mind the downward strain in setting up the shrouds and stays.

A system very generally carried out is to carry the angle bars across the mast or along the length of the top of the cheeks, as shown at page 102, Fig. 60. It will be at once seen that here we are entirely dependent upon the line of rivets connecting the cheeks to the masts. We rest on the rivets below, we hang on the rivets above.

It may be that this is sufficiently strong, but we doubt it, having seen more than once a ship disabled through the giving way of the rivets, and it may be depended upon that when a cheek plate works loose, we have not long to wait until it bulges or buckles in front.

Another plan is to carry the angle bar round the back of the mast. In this case we cut a piece out of the back of the cheek plate to let the bar in; we then put a small piece of angle-iron on the after side of the cheek, as shown,


Topmast Sheave
Top
Hounding Hoop
Fid
Top
Check Angle
Wedging Bar
Sling Plate
Fig 64
Bulb Iron
Coping
Sling
Mast
Truss Bar. Truss Bow.
Sling and Truss Hoops
Truss Hoop
Jack Stay
Futlock Gland

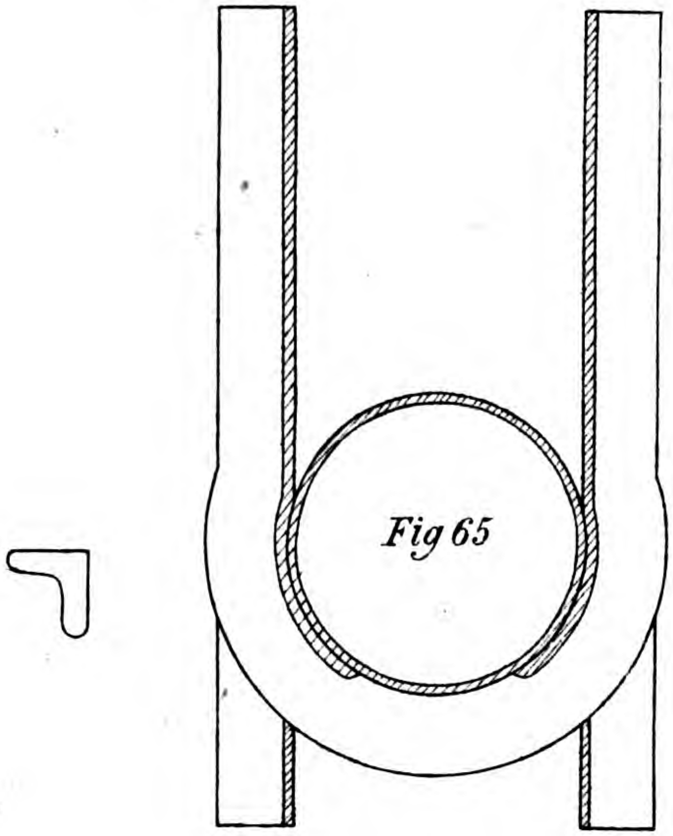


Fig 65

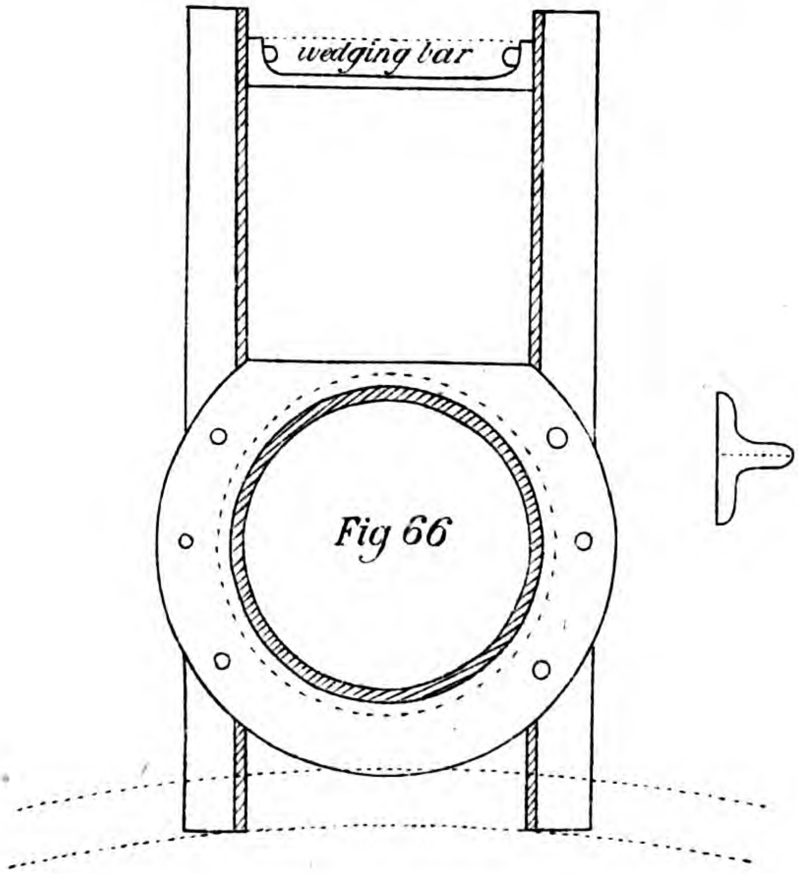


Fig 66

to carry the round-top. This is the method generally adopted in Admiralty ships, and it has advantages over the other that commend themselves at a glance, for, besides being hounded on to, we also get hounded round the mast by a collar, which greatly reduces the strain upon the rivets, and is a good preventive of buckle at the bottom of the cheeks.

Another method very often practised by ourselves is shown in Fig. 64; there we have the elevation. Here, in Fig. 66, we have the plan of hounding. As in the first-mentioned style, we carry the angle bar right across the cheeks; we then put on an angle-hoop, as shown, cutting it across in front at the required breadth; here we rivet on a piece of angle-iron. We also cut across at the after side, as shown in Fig. 66. To clear the round-top we can put in two or three holes, if desirable, for a fairleader.

In Fig. 67 we have a sketch of a bowsprit, showing the cap and saddle hoop; we also see the vertical or diaphragm plate, according to Lloyd's Rules. Bowsprits above 24 inches in diameter must be fitted with the plate. It will be seen how we have shaped it at the outer end, in order to render it elastic to come and go in pitching, as we think that being put in straight across it would be too sudden a break-off from the stronger to the weaker, and would have too much stiffness at this point.

The bowsprit plating is carried out in the same manner as the masts, except that there will be holes in the centre of each course for bars, as shown. We may notice here that all bowsprits above 24″ diameter have bars as well as diaphragm plate. The case is different with masts, as for masts above 24″ diameter, we must either have bars or three plates in circumference. Above 30″ in diameter we must have bars or else four plates in circumference.

The several fittings of a bowsprit we need not notice here, as they are matters of detail and belong more to the smith than the mastmaker, and the knowledge of them would in no way assist the mastmaker in his work.

The projection with the hole through it at the top side of the cap is for the purpose of connecting the foretopmast stay.

The inner hole at the bottom is for bobstay connection. The outer hole at bottom connects the martingale.

Before we proceed further, it might not be out of place to examine a little into the utility of putting bars inside of a mast, and see that we get something like value out of the quantity of material so applied. It is apparent that in punching the rivet holes in the middle line of the plates we reduce the strength of the plates on both the side of tension and the side of compression. It will not do to say that we fill the holes with rivets, as this brings us but a small way back to our complement of solid plate strength, so that to make the mast stronger with bars we begin by first making it weaker with holes to receive those bars, which before their own value can be reckoned must repay and make good out of themselves the loss of strength occasioned by punching these holes. But if we must have bars, why not put them on the outside of the mast, when we shall get more value out of the quantity of material so applied.

We are met with the objection that the angles being outside of the mast, would not be ship-shape nor handsome in appearance.

This is a frivolous objection, when we already put the butt-straps outside the masts, and no two of them opposite each other, but more like the steps of a spiral stair, and would appear to the uninitiated as if the intention was to scale the mast by the spiral ladder.

We believe that a mast constructed from this channel iron, having the flanges outside in a uniform straight line, the whole length of the mast would have a much superior appearance to the spiral butt-straps, and one of the flanges could act as a jackstay.

But the primary object required is strength, that is, economical strength as applied to bridge-girder construction, for we look upon an iron mast with the different strains more in the light of bridge-girder than either boiler or shipbuilding construction.

We do not think it necessary to give data for this, for we find the question solved in "Fairburn and Kirkaldy's Experiments," which we have before us as we write; also "Strength of Materials as applied to Shipbuilding," by the late Professor Rankine, who, in Iron Beams, Fig. 14 E, page 143, shows a beam the counterpart of a mast loaded and strained in the same manner, with details and data for hollow iron tubes.

Then taking an iron mast as a hollow beam or girder, and the object sought the minimum weight of mast combined with the maximum amount of strength, we think we come near our object by constructing our mast with channel iron, having flanges outside.

Steel, as applied to mastmaking, will give us lighter construction, but its cost and treacherous character have hitherto condemned it as a material to be depended on for mast construction; for we may get a number of steel plates all that may be desired, and very likely get one or more from the same lot, and makes not a whit better, but if anything worse, than cast-iron, from brittleness, short hardness, which makes it necessary to examine minutely every plate, and test them well before being put into the mast, as the cutting out of a defective plate cannot but do the mast a considerable amount of injury.

We have drawn out a plan of a mast, with details (but it is too large to be inserted here), with this channel, and curve shaped iron, and we find that with little more than one-half the iron, and about one-half the cost for labour, that a mast of this sort could be made, having equal strength with a mast of the ordinary construction, by simply having the angles outside and solid. The objection of chafing that we have met with is not worthy of notice, and can easily be reduced to a minimum, as we would weld the bars up the whole length of the mast, thus doing away altogether with butt-straps.

We would also telescope the topmast into the standing or lower mast, to work up or down as required, thus doing away with the cap, an item of some importance.

Iron topmasts are so plain and simple in construction that we need notice them shortly. The work will be carried out in the same manner as in the lower mast, with this difference, that we have no lap, as topmasts are mostly flush-jointed both at seams and butts.

Iron yards are also very simple and easy to lay off; the work is the same as in masts, except that they are mostly single riveted in the lengthwise lap, and being of less scantling, the common practice is five-eighth inch riveting for two-thirds in the middle of the yard, the rest half-inch riveting.

In Fig. 68 we are shown the half of a yard, with overlapped butts, and doubled at the centre; this is a very general method, and has the advantage of doing away with one-half of the butt-strap and rivets that would be required in a flush-jointed yard.

Here we begin by numbering our butts from the centre to the ends, the centre being No. 1 and so on outwards to the ends; we scale and mark on the diameter at each butt the same as in masts, but in marking off the yard plates we must subtract three times the thickness of the iron from the size of the underlap plate at the butt. This gives us the inner and the outer half hoop. It will be seen that the numbers, odd and even, each have their own side of the yard; we make the odd numbers the inside course of plates, and flush jump No. 1 butt with a strap to get a plane surface for our outside doubling plate.

In Fig. 69, we have a portion of the yard, with truss and sling hoops, the same as shown on the mast.

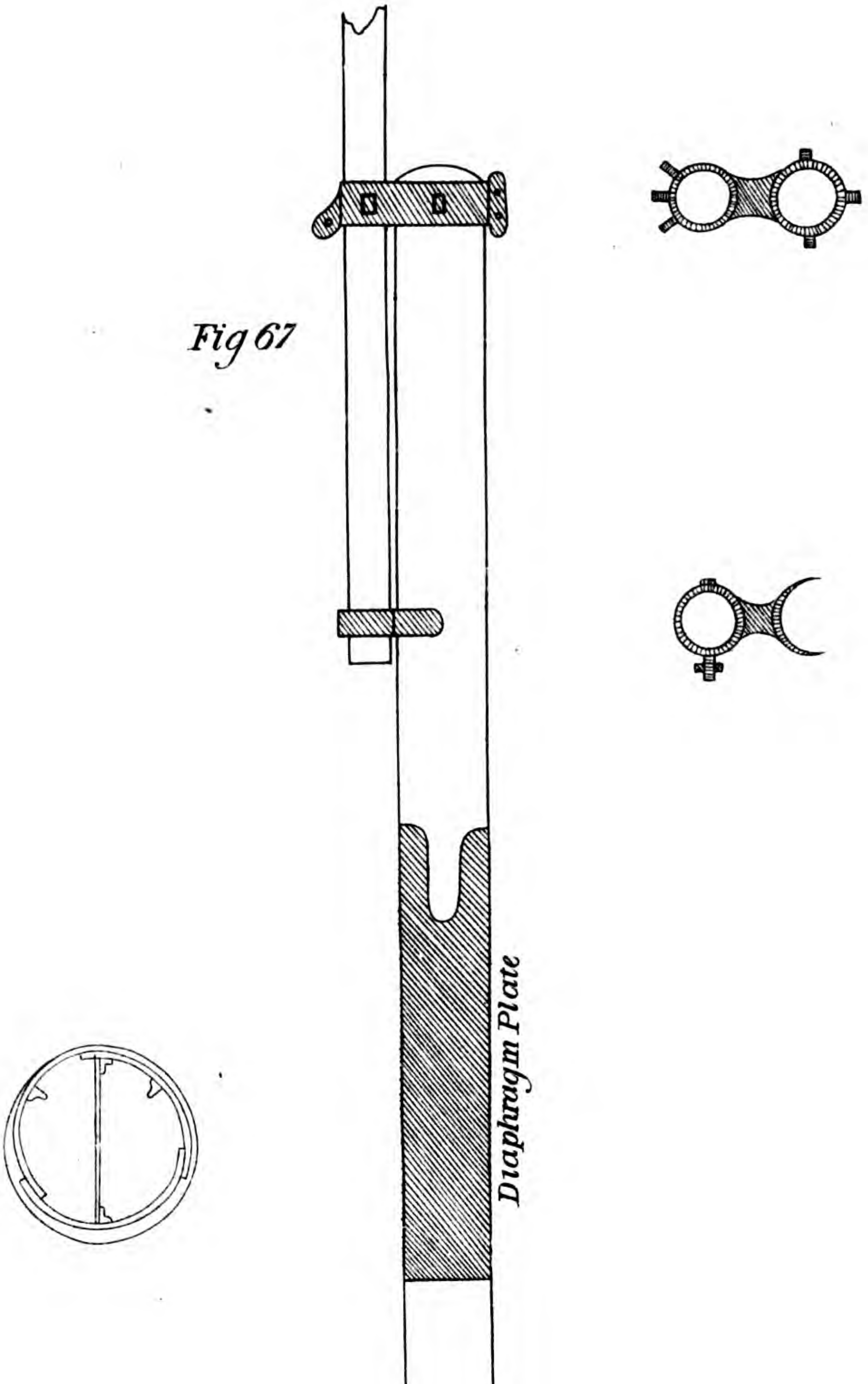


Fig 67

Fig 68

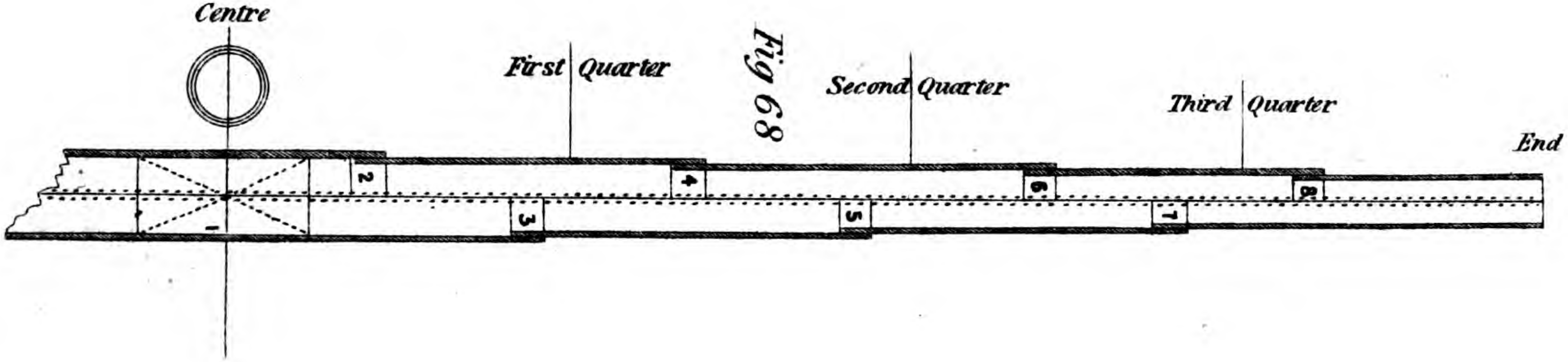
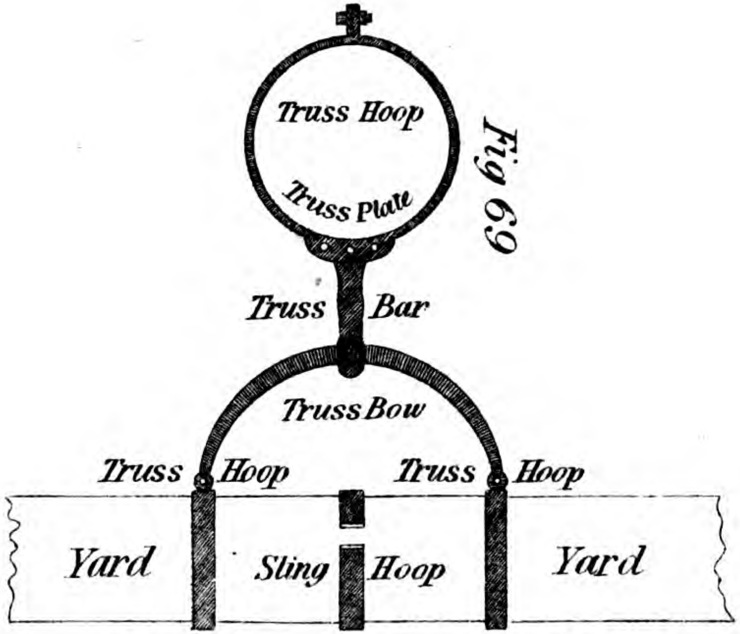

Centre
First Quarter
Second Quarter
Third Quarter
End
1
2
3
4
5
6
7
8

Fig 69


Truss Hoop
Truss Plate
Truss Bar
Truss Bow
Truss Hoop
Truss Hoop
Yard
Sling Hoop
Yard

In Fig. 70, we have the sectional dimensions of the lower and topsail yards for a ship of 1400 tons, with their diameters at the centre quarter and ends, to give a fair curving taper. This plate is useful to the smith for his sizes of hoops, &c. He can make them near the sizes, but not welded until ready for fitting on, when he can shut them up, and put on hot to ensure a good fit. As in the case of the masts, we lay out a Table of Sizes for the lower yard, without taking into account the thickness of the iron, which will make the yard once the thickness of the iron larger than the given sizes :—

LOWER YARD. TABLE OF SIZES.

Mark on Plate A.	No. of Butt.	Size.	Size.	No. of Butt.	Mark on Plate B.	No. of Butt.	Size.	Size.	No. of Butt.
1	2	o 13¾	o 13¾	2	1	1	o 13¾	o 13$\frac{7}{16}$	3
2	3	W 13$\frac{3}{16}$	o 13	4	2	3	W 12⅞	o 12$\frac{5}{16}$	5
3	5	W 12$\frac{7}{16}$	o 11$\frac{3}{16}$	6	3	5	W 11¾	o 9$\frac{11}{16}$	7
4	6	W 10⅝	o 7⅜	8	4	7	W 9¼	6¼	END.
5	8	W 6$\frac{15}{16}$	6¼	END.					

Plate Length, 10″8.

DIAMETERS.

To Measure Outside of Plate.

Butt.	Diameter.	Butt.	Diameter.
2	19½	1	18¾
4	18½	3	18¼
6	16¼	5	17
8	11½	7	13½
END.	10	END.	9½

We think we may state that we have here sketched out and laid down a system of practical iron-mast construction, so simple in detail as to be easily understood by the plater who has mastered the alphabet and the first four rules of arithmetic. It is seen that every plate in the job is a plan of itself, and entirely independent of others until put together in the mast or yard; with our table of plates and sizes, we can mark off at once any single plate in the job. In the case of laying out the mast in course for marking off, we cannot go on until all the plates have arrived at the shipyard, or, as it may happen, the mast building yard, as a course of plates must be complete before we could lay on the sheer battens. We could not lay on the template with one or more plates short of the complement on account of it being continuous and indefinite as to plate lengths. In the case as sketched out here, we can begin the work as soon as any number of plates arrive, and mark off and punch the first that comes to hand, taking care to table the plates as they are marked, to prevent duplicates, or marking more than one plate for one place in one mast, as it often happens that two or more plates in a mast may be nearly one size. When the rest of the plates arrive we have but to refer to our table, when we see what plates to mark, and go on until the table is filled, and the complement of the plates punched according to table. In the case of laying out in courses, we have known a job to be delayed for a considerable time through the non-arrival of one or two plates in the middle of a course. This cannot happen in the single plate process.

It sometimes occurs that the work is delayed through one or more defective plates, and they are mostly found out after nearly being in a finished state, when we find the time and labour required for good work thrown away upon slag-holed, blistered, or fractured plates. The place and time to find them out is at the process of bending; the plate being hot and bent to an acute curve in the rolls, at once exposes any

Fig 70

Length extreme 76'-0"

Diameter at Centre 19^{in} Plating $\overset{6}{16}$

..	1st Quarter		18½"	..	$\overset{5}{16}$
..	2nd	..	17⅛	..	$\overset{5}{16}$
..	3rd	..	14¼	..	$\overset{4}{16}$
..	Ends	..	9½	..	$\overset{3}{16}$

Doubled at Centre 6 feet

Length extreme 68'-0"

Diameter at Centre 17" Plating $\overset{5}{16}$

..	1st Quarter		16½	..	$\overset{5}{16}$
..	2nd	..	15¼	..	$\overset{5}{16}$
..	3rd	..	12¾	..	$\overset{4}{16}$
..	Ends	..	8½	..	$\overset{3}{16}$

Doubled at Centre 5 feet

Length extreme 62'-0"

Diameter at Centre 15" Plating $\overset{4}{16}$

..	1st Quarter		14⅝	..	$\overset{4}{16}$
..	2nd	..	13½	..	$\overset{4}{16}$
..	3rd	..	11¼	..	$\overset{3}{16}$
..	Ends	..	7½	..	$\overset{2}{16}$

Length extreme 55'-0"

Diameter at Centre 14½" Plating $\overset{4}{16}$

..	1st Quarter		14⅛	..	$\overset{4}{16}$
..	2nd	..	13⅛	..	$\overset{4}{16}$
..	3rd	..	10½	..	$\overset{3}{16}$
..	Ends	..	7	..	$\overset{2}{16}$

flaw that may exist in the plate. Now it is bad enough after all the work is done that is requisite for a good plate, to find our labour thrown away upon a bad one; but it is a great deal worse when we know that, before we can replace the bad plate, we must expend more labour upon it by putting it in the furnace; when, after it is hot again, we must level or straighten it out on the blocks in order to make a template of it, to mark off a plate to replace it. Observe the time and labour that is uselessly wasted after the plate has been condemned, simply to get a template of it, and we have known cases where as many as half-a-dozen plates have been condemned in one job after being bent to shape. One can imagine the feelings of a man in a case like this having charge of the work. This is the result of, and belongs to the laying out in courses process, as no one plate has a defined size or template of its own. The mould loft laying off and wood frame template, is to be preferred in a case of defective plates, as, although costly at first production, any one template of wood must certainly be cheaper than a solid iron plate, and requiring to be first made level before it can be used.

When we come across a defective plate, let its state of advancement and the work expended upon it be what it may, we at once throw it aside without further trouble. As we carry the template for all the plates in our pocket, we have only to know the numbers at the butts of the condemned plate, when, by referring to our table, we at once find the counterpart in number of plate and sizes of butts; we have only to take a new plate, square it off to sizes given in table, lay on plate length template, mark, punch, and countersink, which can be done in one-fourth of the time, and none of the labour in straightening out the defective plate. Referring to table of sizes, it will be seen that, should any plate prove bad, we have its measure taken beforehand, and whatever shape it has assumed before its condemnation it carries back along with it to the place of its birth and the maker. We remember a case that happened in our hands where a plate was condemned after being riveted into the mast on account of being sand and slagholed, the plate having escaped observation in the course of the work. The job was nearly finished, and required despatch. Well, we did not wait until the plate was cut out to get it for a template; our first business was to put on four drillers to drill the countersinks off, next to get a plate. We had our table in our pocket, and proceeded with the plate, and had it ready for berthing in the mast before the other was nearly cut out; the only time occupied was in taking out the bad and putting in a new plate.

We have said sufficient to prove that the system of practical mast-plating, as laid down and carried out in our case is, if not the best, at least a good one, so far as good work and economy in production is concerned, and we require but little room, as any small out of the way corner is sufficient, seeing that there is no laying out, and we run no risk of getting our marking off destroyed by weather.

RIVETING.

Riveting is a subject of primary importance in iron-mast making, for a great deal depends upon the skill of the riveters whether a mast or yard, when finished, has fair lines and be without twist. We speak on this from experience, as we have known cases of sets of riveters, who on a ship's side were all that could be desired, whilst to put them on to a mast and give it into their hands fair and a straight job, the chances were that, unless well watched, they would leave it in anything but the shape they found it, their mind apparently being set that their object and mission was fulfilled in filling up the rivet-holes in the shortest possible time, paying no regard to looseness of a bolted mast or yard, as compared to a ship's side. It is the practice in some yards to give the mast riveting to the apprentices, so simple is it looked upon by those having authority, but then they must place a foreman, whose whole time and attention is occupied over them to see that they make the work good; and, as showing the skill possessed by some of our foremen, we will mention a case that came under our notice a short time since. We had occasion to pass two iron masts, one of which had evidently been started upon by the riveters a few hours previous. The one in course of riveting was considerably bent just where the riveters were working, and no wonder, for the mast was resting on both ends, and hanging in the middle with the butts spring; again, the mast just plated was straight and butts close. We took the liberty to call the attention of the foreman in charge, with the remark that the riveters were spoiling the mast. The answer we got from him was, "What business of ours was it, or what did we know about it." We replied that it was ours and everybody's business to prevent good work being spoiled through carelessness by respectfully calling attention to it; and, as for our knowledge, it did not require the eye of a genius to see that the mast was not straight. The answer we got from him was a closer, and to the effect that we were fools to talk about a straight mast, for how could a mast be straight when it was tapered at both ends. This, of course, was a settler, and sent us on our way in a reflecting mood.

We made it our business to have a look at this job when finished, and have no hesitation in stating that it was reduced from a good to a bad job to the extent of 50 per cent., entirely through want of skill and carelessness in riveting.

We quite agree with an author on boiler making, whose work is on our table before us, that it is necessary for men who aspire to the honourable position of foremen, that they should pass an examination as to fitness for the situation.

A number of our shipyard foremen are neither more nor less than bully policemen; and we say that it is impossible for a man who aspires to be a first-class mechanic to obey and carry out the orders of a foreman who, he is convinced, is only a dummy as a tradesman, and he repines at the misfortune that places him under such a man.

We must not be understood to apply the foregoing remarks to our foremen as a class; far from it, for we personally know many men who deservedly stand high in the estimation both of employers and workmen, and who fill their positions with honour to themselves and credit to the trade to which they belong; and there is a degree of natural pride in a workman who serves under men of this stamp, which is not to be wondered at when he knows that he is led by a foreman who is master of his trade.

We believe that it is the best and most economical way to put the riveting of the masts and yards into the hands of skilled riveters, paying a good price and making them responsible for the quality and character of the work they perform. Explaining to them that in riveting a seam of rivets, the heat of the rivets, and every blow of the hammer draws the iron to the seam, expands and lengthens, and creates a tendency to bend, which must be attended to and counteracted. This is simply and easily done by putting in a wedge or altering the position of the mast or yard a little, and various simple methods that are always at hand. The main thing wanted is care.

There is another thing in riveting that deserves a little attention; we mean the drop-holes that are cut in the middle of the plate to pass the rivets inside to the holder up. We have always looked upon these holes, not only in the light of reducing strength, but as an unsightly abomination to be avoided, and regarded them always as a plague. To get our masts riveted without these holes, we adopted the expedient of riveting up in segments or portions of a mast; that is, we drew our work together in three or four separate pieces. After riveting up, while we drew them together one by one at the connections, tossing the rivets in at the ends as we put them together. By this means we abolished the drop-holes, and found our work as fair and as well done as if riveted in a whole mast. Of course we require no drop-holes in a yard, as we rivet them up plate by plate.

We strike a chalk line up the middle on the back of each plate as we put it on the yard. We see that it corresponds with similar lines on the plates in the yards, also that the lap-line of rivet holes are straight, then we put in the rivets; by carrying this method out from the centre to the end of the yard, we can rely with confidence on having a yard with straight lines, fair proportions, and regular taper.

CALKING.

As far as calking a mast or yard is concerned, we will make short work of the subject by stating our belief that neither a mast or yard require or ought to be calked; indeed we are largely imbued with the idea that calking a mast or yard does a great amount of harm, by wedging the lap apart at the calked edge with the calking tool, which forms a permanent ridge along the edge of the plate, reducing the faying bearance and cohesive grip of the lap, and in the case of the butts with straps inside, they ought on no account to be calked, for it is plain that we require all the bearance across the thickness of the iron at the butts, without reducing it and making it brittle with the calking tool. As well might a carpenter ridge into a wood mast with his saw, and say it was beneficial to the mast. When we see an iron mast with straps inside, and the butts calked, we make up our minds that the butts have been open and are packed up with the calking tool; and when we see a mast with the laps calked, we cannot help thinking that if they were not close lapped before, they are still further from being close after being calked.

We believe that the term calking as applied to masts is only a more euphonious name for patching up bad work, for, as we have already said in the case of hard close butts and laps, there is no necessity to destroy the work with a calking tool, as we can easily get water-tightness, and at the same time our full complement of strength and faying cohesion. We have no internal pressure, as in the case of a boiler; or external pressure, as in the case of a ship, according to its load and weight. We have nothing more than the pressure of the weight of a few drops of rain, or a few buckets full of sea water thrown against the mast, to provide against, and we can do this best with the paint brush. But if a mast or yard must be calked, then we say (taking into account the wide spacing of the rivets in proportion to the thickness of the iron) that the best plan is to plane the outside lap edges with a small degree of bevel, and calk with a flat-faced tool, holding it at a right angle to the plate edge, and by this means jumping the one iron bodily against the other; as we have already stated, we look on a mast as girder or beam, where strength, combined with lightness, is of first importance, and water-tightness of a secondary character. In iron bridges with iron flooring over a roadway, we do not iron calk the floor or girders for water tightness; we get this and preserve the iron at the same time by laying on pitch and gravel, concrete, cement, &c.

There are one or two small matters in the plating of the work that it may be worth while to take a little notice of. In bending a mast plate at the rolls, care should be taken to get the plate half through the rolls, and set fair to a centre line before screwing down the top roll; having got the plate set fair, and the top roll bearing, then proceed to bend up, taking care not to let the plate out at the edges until bent up; by this means we get the plate bent up without twist, and do not require to re-heat it to get fair.

In the bending of a plate at the rolls, there is about six inches of the edge of the plate that the rolls do not affect; we find that by bringing this up to the required curve with hammers, that the edge of the plate or lap expands in length, causing the back of the plate to be hollow, and is very troublesome when putting the work together. To get over this, and when the plate is in the rolls, but before it is thoroughly bent up, we lay a piece of flat half-round iron about three feet in length on the edge, about three inches in, shifting it along the plate as the roll works out. This saves a vast amount of labour as compared to the hammering up.

Forging the cheek plates to shape can be done in several ways.

They can be done at the rolls if they are convenient to the furnace. They can be recessed down between two blocks, but this method hammer marks greatly—a thing to be avoided.

We think the method as shown at Fig. 71 a good one, and much easier. We bend a bit of stiff plate to the curvature of the mast at the hounds, and just broad enough to let the cheek plate come to the block, as shown; the holes in cheek plates being punched, we also punch a hole at each end of the service plate, making one of them oblong, or like a slot-hole, to allow for hot expansion. Having fixed the service plate to the block, we forge our cheek plates over it, as shown, putting in dugs to keep the plate in position. After placing the plate in position, we drive it down at first with heavy wooden mallets, then work along the knuckle with the tool, as shown, and level all down to the block, as shown; we have pins introduced one at each end to keep fair. This method is the same as if we bent the cheek plates over the mast.

It often happens that the rolls are too large to bring a yard plate up to the required curve; in that case we first roll them up as far as practicable, avoiding too close a pressure between the rolls, as, when too closely pressed, they mangle the plate ends, and burst out at the holes.

Having got as much as we can at the rolls, our plate will very likely be something in shape as Fig. 72.

Well, to get them to the curvature wanted, we re-heat them and squeeze them together to the required diameter, as shown in Fig. 73. Having got the plate to the diameter between two bars, we find that it has bulged up on the back, and shaped like a half ellipse, but we must have it round, and to avoid mallet or hammer marks, we go along the back or top of the plate with a hard wood swedge, as shown in figure, until we bring it round, all the time having it pinned at the bars to its diameter.

In estimating the working modulus of strength for hollow iron or steel masts and spars, regard must be had to the fact

Fig 71.

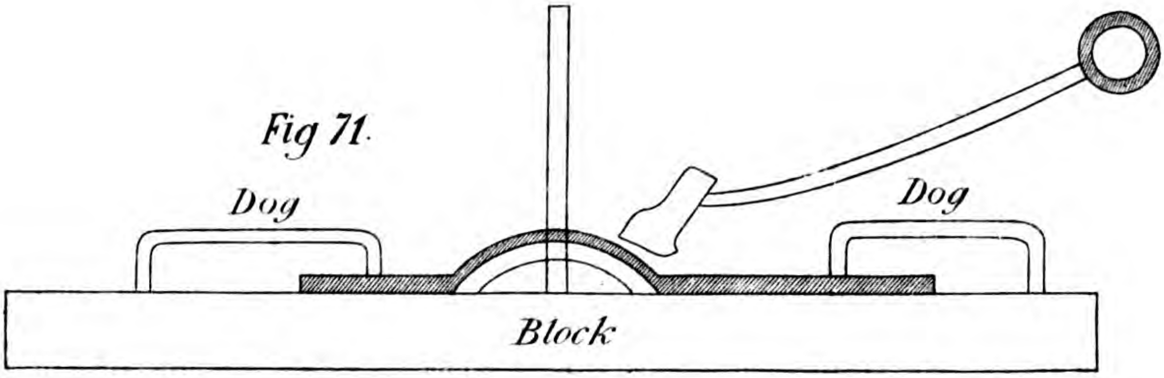


Fig 73

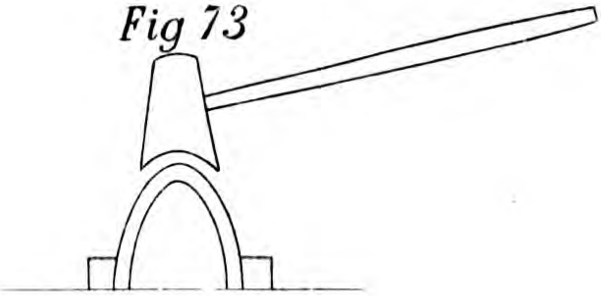


Fig 72

that thin tubes of iron or steel usually give way to a bending load by brickling at the compressed side.

If the working modulus for iron under these circumstances be estimated at 7½ times, and that for steel 10 times the working modulus for wood, the following results are obtained :—

Iron ... ... $\dfrac{\textit{thickness},}{\text{diameter},} = \frac{1}{8} \times 7\frac{1}{2} = \frac{1}{60}$

Steel ... ... $\dfrac{\textit{thickness},}{\text{diameter},} = \frac{1}{8} \times 10 = \frac{1}{80}$

The following are the proportions prescribed by Rule 21 and table No. 8 of the Liverpool registry :—

	Thickness. Diameter.
Iron masts	from $\frac{1}{53}$ to $\frac{1}{70}$
Iron yards	„ $\frac{1}{43}$ to $\frac{1}{60}$
Steel yards	„ $\frac{1}{60}$ to $\frac{1}{80}$

TAPERING OF MASTS AND SPARS.—The diameter of masts and spars at the quarters or parts intermediate between the greatest and smallest diameters are not regulated by any theoretical principle, but are merely led off so as to give a fair convex curvature to the outline. The distance from the given diameter to the small diameter is divided into four equal intervals, and the points of division are called respectively the first, second, and third quarters. In a lower mast the points of division between the partners and the heel are called the lower quarters, and those between the partners and the hounds the upper quarters.

Then dividing the whole taper or difference between the given diameter and the small diameter into sixteen equal parts, those parts are to be thus distributed in order to give the fairest possible curvature :—

Diameter at first quarter = given diameter $\frac{1}{16}$ whole taper.
„ second „ = „ $\frac{4}{16}$ „
„ third „ = „ $\frac{9}{16}$ „

Full rigged ship, stations for masts, in fractions of line of flotation from the middle :—

Mizzen-mast. Abaft.	Main-mast. Abaft.	Fore-mast. Afore.
From 0·4 to 0·3.	From 0·08 to 0·03.	From 0·4 to 0·3.

The centres of the square sails on a mast are about ·05 of the extreme breadth before the station of the mast :—

Rake of Fore-mast, aft	... ...	1 to 36, or nearly ⅜ per foot.
„ Main-mast, aft	... ...	1 to 12, or 1 inch per foot.
„ Mizzen-mast, aft	... ...	1 to 12, „ „
Steve or bowsprit	...	from 1 to 3, to 1 in 2, or from 4 to 6 inches per foot, Fincham's rules.

The rake of a ship's mast, as at present set up, does not exactly agree with the above table, taking our experience to guide, as we say that the following table of rakes is mostly used at present :—

Sailing Ship.		Steamer.	
Fore-mast ...	½ inch per foot.	Fore-mast ...	1¾ inches per foot.
Main-mast ...	⅝ „ „	Main-mast ...	2 „ „
Mizzen-mast ...	¾ „ „	Mizzen-mast	2¼ „ „
Bowsprit ...	... ...	...	from 3 to 6 „ „

Proportions of standing masts, ships or brigs :—

Position of given diameters.	Ratio of given diameter to length from heel to hounds.	Ratio of end diameter to given diameter.
At the wedging deck	... $\frac{1}{40}$ to $\frac{1}{38}$ ...	Head ... ·67 to ·75. Hounds ... ·75 to ·80. Heel ... ·83.
Bowsprit at the bed	... $\frac{1}{25}$ to $\frac{1}{20}$ ...	Ouver end ·67. Heel ... ·83.

Proportion of lower and topsail-yards. Ships and brigs :—

Position of given diameters.	Ratio of given diameter to length.	Ratio of end diameter to given diameter.
Lower, at slings ...	... $\frac{1}{40}$ to $\frac{1}{50}$ ...	... Arms .. .. ·5.
Topsail „ ...	... $\frac{1}{50}$ to $\frac{1}{60}$ ...	... Arms ... ... ·5.

We are only noting the proportions and ratios of the lower mast and yards, or what is connected with the work commonly passing through the hands of an iron mastmaker. As the upper and lighter masts and spars are mostly of wood, we will be content to leave them in the hands of the wood mastmaker, paying most attention to what more immediately concerns the work in our own hands.

In the absence of specific instructions we have found the following rule for masts useful, and it approximates very nearly to the requirements of Lloyds' and the Liverpool Registry :—Given the length of a mast, divide by three for the wedging diameter, divide by four for diameter at foot, and divide by four and a half for diameter at head of mast.

Note.—For a mast of this length it would be well to allow 1 inch greater diameter at the deck. Then

$90 \div 4\frac{1}{2} = 20''$ ... ... Head of Mast.
$90 \div 3 = 30''$ ... ... Wedging Deck.
$90 \div 4 = 22\frac{1}{2}''$ ... ... Foot of Mast.

For a lower yard we take twice the beam of the ship, with 10 per cent. of twice the beam additional. Thus the beam of the ship is say 36 feet.

Suppose a mast and the length given 90 feet. Then

Length of Yard.
$36 \times 2 = 72 \times \frac{1}{10}$ of 72 ... 79 feet $2\frac{4}{10}$ inches.
Diameter at Slings.

Divide the length of yard by 4, then we have 20 inches nearly; divide the diameter at slings by 2, and we have 10 inches diameter at ends.

The length of a royal yard is once the beam of the ship, and the length of the intermediate yards are taken from a line extending from the lower yard arm to the royal yard arm, as shown in Plate A, when the distance intervening between each yard is known, and having the length of lower and royal yards, the length of the other yards can be easily calculated.

Lloyds' and the Liverpool Registry Rules stipulate that for a mast of 24 inches diameter and under 2 plates in circumference, 3 plates or two plates with bars in circumference.

Above 24 in. and under 30 in. in diameter. } 4 or 3 plates, with bars
„ 30 „ 36 „ } in circumference.

Bowsprits above 28 inches diameter must have bars and diaphragm plate extending from within the wedging to the gammoning connected by continuous angle-irons to the upper and lower parts of the bowsprit, and two additional angle-irons of the size given in the table ; add bowsprits 28 inches in diameter and under to have an angle-iron at the centre of each plate extending the whole length of the bowsprit.

All masts of 84 feet in length and above to be fitted with angle-iron, properly shifted, and extending the whole length of the mast. If the plates be arranged as described in the tables there should be an angle-iron fitted to each plate in the round of the size given in the table.

The mast and bowsprit plates should be doubled in the way of the wedging, or otherwise efficiently strengthened. The heels of all masts and their steps should be efficiently strengthened.

The cheeks of masts should be stiffened by angle-irons or cope iron on their foremost edges, or by some other approved plan.

SIZES AND SCANTLINGS FOR MASTS AND BOWSPRITS OF SAILING VESSELS AND FULL-RIGGED STEAM VESSELS. LLOYDS' REGISTER, 1878.

IRON MAST.

	Length.	Partners		Heel.		Hounds.		Heads.		Sizes of Angle on Masts.	Cheeks.	
		Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.		Thickness of Plate.	Sizes of Angle Iron.
2 Plates.	48	17	$\frac{5}{16}$	13	$\frac{4}{16}$	$13\frac{1}{2}$	$\frac{4}{16}$	$11\frac{1}{2}$	$\frac{3}{16}$	...	$\frac{7}{16}$	$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{6}{16}$
	51	18	$\frac{5}{16}$	$13\frac{1}{2}$	$\frac{4}{16}$	14	$\frac{4}{16}$	12	$\frac{4}{16}$	...	$\frac{7}{16}$	$3\frac{1}{2} \times 3 \times \frac{6}{16}$
	54	19	$\frac{5}{16}$	14	$\frac{4}{16}$	15	$\frac{4}{16}$	13	$\frac{4}{16}$	...	$\frac{7}{16}$	$3\frac{1}{2} \times 3 \times \frac{6}{16}$
	57	20	$\frac{6}{16}$	15	$\frac{5}{16}$	16	$\frac{5}{16}$	$13\frac{1}{2}$	$\frac{4}{16}$	...	$\frac{8}{16}$	$4 \times 3 \times \frac{7}{16}$
	60	21	$\frac{6}{16}$	16	$\frac{5}{16}$	17	$\frac{5}{16}$	14	$\frac{5}{16}$	...	$\frac{8}{16}$	$4 \times 3 \times \frac{7}{16}$
	63	22	$\frac{6}{16}$	$16\frac{1}{2}$	$\frac{5}{16}$	18	$\frac{5}{16}$	15	$\frac{5}{16}$	...	$\frac{8}{16}$	$4 \times 3 \times \frac{7}{16}$
3 Plates.	66	23	$\frac{6}{16}$	17	$\frac{5}{16}$	$18\frac{1}{2}$	$\frac{5}{16}$	$15\frac{1}{2}$	$\frac{5}{16}$	...	$\frac{8}{16}$	$4\frac{1}{2} \times 3 \times \frac{7}{16}$
	69	$24\frac{1}{2}$	$\frac{6}{16}$	18	$\frac{5}{16}$	19	$\frac{5}{16}$	16	$\frac{5}{16}$	...	$\frac{8}{16}$	$4\frac{1}{2} \times 3 \times \frac{8}{16}$
	72	26	$\frac{6}{16}$	19	$\frac{5}{16}$	20	$\frac{5}{16}$	17	$\frac{5}{16}$	...	$\frac{8}{16}$	$4\frac{1}{2} \times 3 \times \frac{8}{16}$
	75	27	$\frac{7}{16}$	$19\frac{1}{2}$	$\frac{6}{16}$	21	$\frac{6}{16}$	$17\frac{1}{2}$	$\frac{6}{16}$	...	$\frac{9}{16}$	$5 \times 3 \times \frac{9}{16}$
	78	28	$\frac{7}{16}$	20	$\frac{6}{16}$	22	$\frac{6}{16}$	18	$\frac{6}{16}$	...	$\frac{9}{16}$	$5 \times 3 \times \frac{9}{16}$
	81	29	$\frac{8}{16}$	21	$\frac{6}{16}$	$22\frac{1}{2}$	$\frac{6}{16}$	19	$\frac{6}{16}$	...	$\frac{9}{16}$	$5 \times 3\frac{1}{2} \times \frac{9}{16}$
	84	30	$\frac{8}{16}$	22	$\frac{6}{16}$	23	$\frac{6}{16}$	$19\frac{1}{2}$	$\frac{6}{16}$	$3\frac{1}{2} \times 3 \times \frac{7}{16}$	$\frac{10}{16}$	$5 \times 3\frac{1}{2} \times \frac{9}{16}$
	87	31	$\frac{8}{16}$	$22\frac{1}{2}$	$\frac{6}{16}$	24	$\frac{6}{16}$	20	$\frac{6}{16}$	$4 \times 3 \times \frac{7}{16}$	$\frac{10}{16}$	$5\frac{1}{2} \times 4 \times \frac{10}{16}$
4 Plates.	90	32	$\frac{8}{16}$	23	$\frac{7}{16}$	25	$\frac{7}{16}$	21	$\frac{6}{16}$	$4 \times 3 \times \frac{7}{16}$	$\frac{10}{16}$	$6 \times 4 \times \frac{10}{16}$
	93	33	$\frac{9}{16}$	24	$\frac{7}{16}$	26	$\frac{7}{16}$	$21\frac{1}{2}$	$\frac{6}{16}$	$4 \times 3 \times \frac{7}{16}$	$\frac{11}{16}$	$6 \times 4 \times \frac{10}{16}$
	96	34	$\frac{9}{16}$	25	$\frac{7}{16}$	$26\frac{1}{2}$	$\frac{7}{16}$	22	$\frac{6}{16}$	$4\frac{1}{2} \times 3 \times \frac{8}{16}$	$\frac{11}{16}$	$6 \times 4 \times \frac{10}{16}$

Where a steamer is intended to be fitted with masts or a bowsprit for auxiliary purposes they may be one-eighth less in diameter than prescribed by table. The mizzen-masts for barques may be reduced one-fifth in diameter from that given in the table, and the plating to be not less than thickness corresponding to the diameters.

Sizes and Scantlings for Masts and Bowsprits of Sailing Vessels and full-rigged Steam Vessels. Lloyds' Reg., 1878.

Iron Bowsprits.

Length of outside bed.	Bed.		Heel.		Cap.		Sizes of Angle Iron
	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.	
14	17½	5/16	14½	5/16	12	4/16	2½ × 2 × 5/16
15	18½	5/16	15½	5/16	12½	5/16	2½ × 2 × 5/16
16	20	5/16	16½	5/16	13	5/16	3 × 2 × 5/16
17	21½	6/16	18	6/16	14	5/16	3 × 2 × 5/16
18	23	6/16	19	6/16	15	5/16	3 × 2½ × 5/16
19	24½	6/16	20	6/16	16	5/16	3 × 3 × 6/16
20	26	7/16	21	6/16	16½	6/16	3½ × 3 × 6/16
21	27	7/16	22	6/16	17½	6/16	3½ × 3 × 6/16
22	28	7/16	23	6/16	18½	6/16	4 × 3 × 7/16
23	30	8/16	24	7/16	19	6/16	4 × 3½ × 7/16
24	31	8/16	25	7/16	20	6/16	4 × 3½ × 7/16
25	32	8/16	26	7/16	21	6/16	4½ × 3½ × 8/16
26	33	8/16	27	7/16	21½	6/16	4½ × 3½ × 8/16
27	35	8/16	28	7/16	22	6/16	4½ × 3½ × 8/16

Suggestions for the construction of Iron Masts, Bowsprits, and Yards.

The iron used in the construction of masts, bowsprits, and yards should be of good malleable quality, and quite free from surface or other defects.

The iron should stand a tensile strain of 20 tons to the square inch, and should be capable of standing the following bending tests when cold without fracture :—

Thickness of Plates.	To bend cold through an angle of—	
	With the grain.	Across the grain.
9/16	25°	8°
8/16	30°	11°
7/16	37°	13°
6/16	47°	15°
5/16	55°	17°
4/16	65°	20°
3/16	70°	25°

The plates to be bent over a slab, the corner of which should be rounded with a radius of half-an-inch.

LOWER MASTS.—The plating should be of the thickness, and the plates arranged as suggested in the table. The seams should be double riveted. The butts below the mast partners in masts, and those inside of the wedging in bowsprits might be double riveted; the remainder should be treble riveted. The butt straps in all cases should be $\frac{1}{16}$ of an inch thicker than the plates they connect, and would be better to be fitted on the outside of the masts and bowsprit.

SIZES AND SCANTLINGS FOR YARDS AND TOPMASTS OF SAILING VESSELS AND FULL-RIGGED STEAM VESSELS. LLOYDS' REG., 1878.

Iron Yards.											Iron Topmasts.						
	Centre.		1st Quarter		2nd Quarter		3rd Quarter		4th Ends			Heel.		Lower part of Head.		Head.	
Length.	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.	Length.	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.
32	8	3/16	7⅞	3/16	7¼	3/16	6	3/16	4	2/16	32	11½	3/16	7¼	3/16	6½	2/16
36	9	3/16	8¾	3/16	8⅛	3/16	6¾	3/16	4½	2/16	34	12	3/16	8	3/16	7	2/16
40	10	3/16	9¾	3/16	9	3/16	7½	3/16	5	2/16	36	12½	4/16	9	4/16	7½	3/16
44	11	3/16	10¾	3/16	10	3/16	8¼	3/16	5½	2/16	38	13½	4/16	10	4/16	8	3/16
48	12	4/16	11¾	4/16	10¾	3/16	9	3/16	6	2/16	40	14½	4/16	11	4/16	9	3/16
52	13	4/16	12⅝	4/16	11¾	3/16	9¾	3/16	6½	2/16	42	15	4/16	11½	4/16	9½	3/16
56	14	4/16	13⅝	4/16	12⅝	4/16	10½	3/16	7	2/16	44	15½	4/16	12	4/16	10½	3/16
60	15	4/16	14⅝	4/16	13½	4/16	11¼	3/16	7½	2/16	46	16	5/16	13	4/16	11	4/16
64	16	5/16	15⅝	5/16	14⅜	5/16	12	4/16	8	3/16	48	17	5/16	14	4/16	11½	4/16
68	17	5/16	16½	5/16	15¼	5/16	12¾	4/16	8½	3/16	50	17½	5/16	15	4/16	12½	4/16
72	18	5/16	17½	5/16	16¼	5/16	13½	4/16	9	3/16	52	18	6/16	15½	5/16	13	5/16
76	19	6/16	18½	5/16	17⅛	5/16	14¼	4/16	9½	3/16	54	18½	6/16	16	5/16	13½	5/16
80	20	6/16	19½	5/16	18	5/16	15	4/16	10	3/16	56	19¼	6/16	16½	5/16	14	5/16
84	21	7/16	20½	6/16	19	5/16	15¾	5/16	10½	4/16	58	20	6/16	17	5/16	15	5/16
88	22	7/16	21½	6/16	19¾	5/16	16½	5/16	11	4/16	60	20½	6/16	18	5/16	15½	5/16
92	23	7/16	22½	6/16	20¾	6/16	17¼	5/16	11½	4/16	62	21½	6/16	18½	5/16	16	5/16
96	24	7/16	23⅜	8/16	21⅝	6/16	18	5/16	12	4/16	64	22	6/16	19½	5/16	17	5/16

SECTION IV.

HOW TO CUT PLATES TO FORM THE RAKE IN A FUNNEL.

Fig. 74 represents the plates which is to compose the funnel.

Fig. 75 represents the funnel. Now, if by applying the square to lines C D, you find 4 inches has to be taken off, as shown at the dotted lines. You must draw line B, Fig. 74, 4 inches from the bottom of the plate. Then draw centre line A, extending it beyond the plates a few feet. Now draw one short line between each of these two divisions, 2 inches long, as shown at E F; take your trammels and extend them to any radius that will enable you to touch line B in the centre and the ends of the short lines E F, and with that radius draw the centre curve line from E to F with the trammels at the same radius you turn on lines G H, which represents the centre of rivet holes, and by placing the point of the trammels on these lines at F and J you draw the curve lines from F to J and E to I.

Fig 75

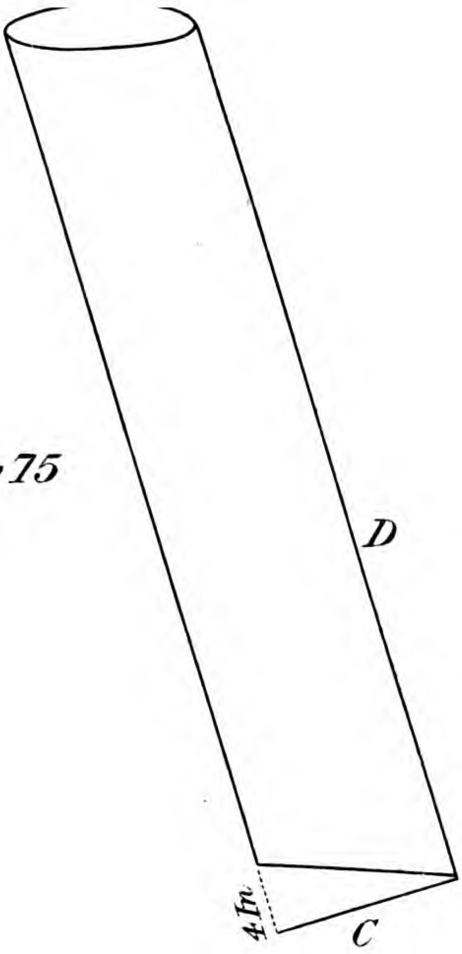
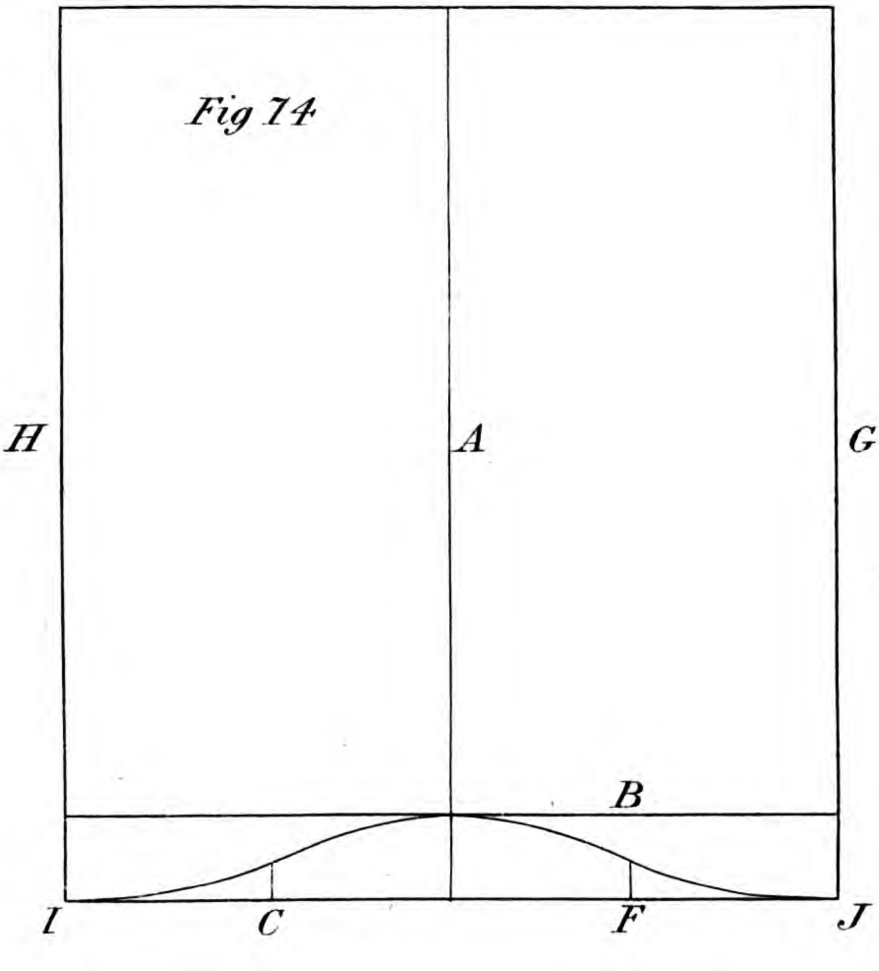


Fig 74



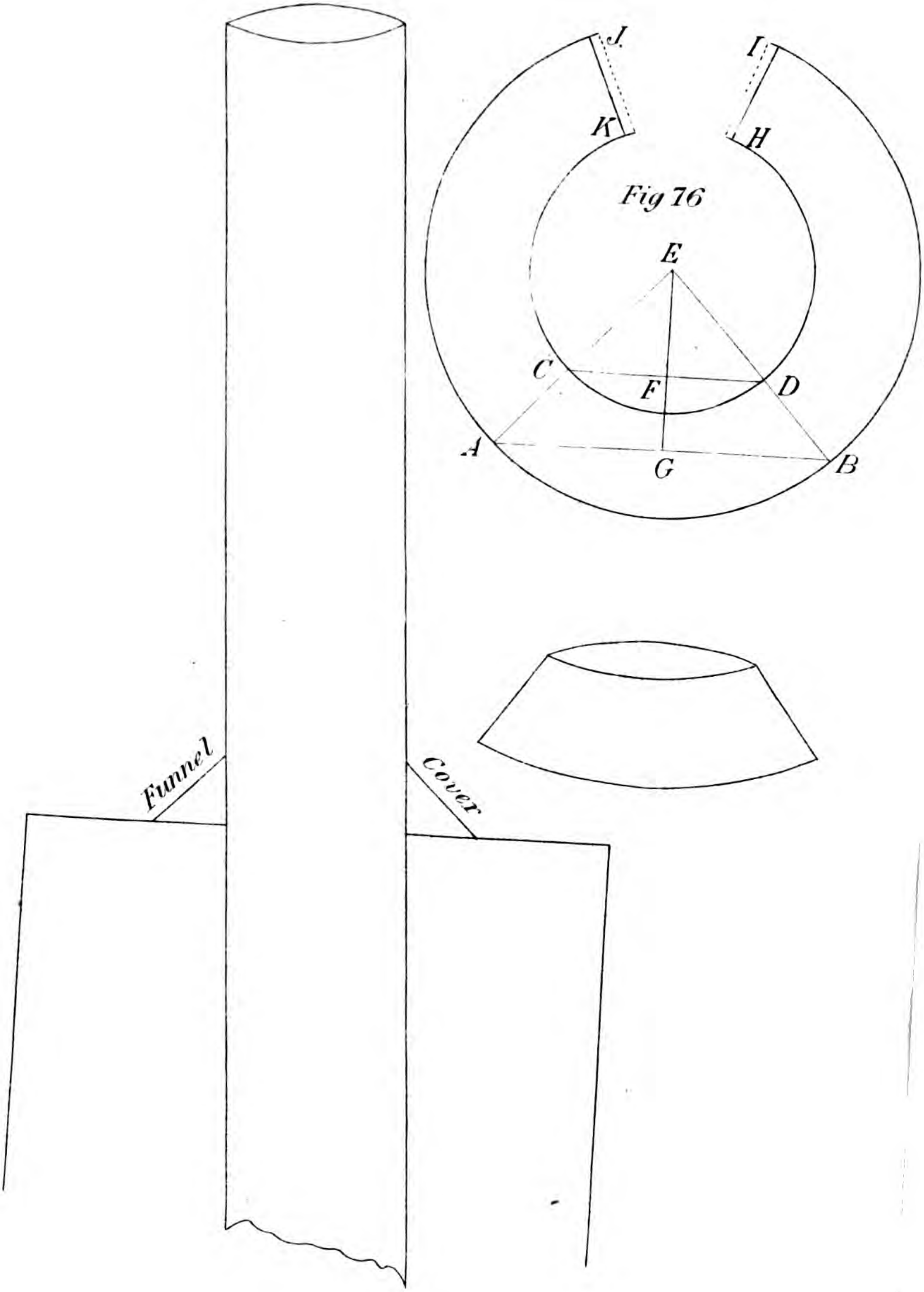


Fig 76

TO DESCRIBE A FUNNEL COVER THAT RESTS ON DECK CASING.

Let A B (Fig. 76) equal diameter of base; C D diameter of funnel; F G altitude. Produce A C and B D until they meet with E as centre and the radii E D and E B, describe the curves I J and H K; set off I J equal to the circumference of the base A B; draw the lines I H and J K, cutting the centre at E; you can divide it into as many plates as you require. In striking the lines for the joints always do it from the centre E. If the circumference of the base is 8 feet, the circumference of the outer circle must be 8 feet. You can soon measure the required length around the circle with a pair of compasses, setting them at 3 or 4 inches. If you require a flange for the inside, it must be allowed from the inner circle.

TO COVER A DOME BY THE FIRST METHOD.

Let A B C (Fig. 77) be the section of a dome. Draw the axis D B; produce to J; divide the curve of one-half the figure into equal parts, as E F G and H, the width of these divisions being the width required by that of the metal with which the dome is to be covered; produce A E, E F, G H, and H B severally, until they intersect the axis B D; then [for example] from the point I, with the radii I G and I F, describe the curves G M, F N; then set off that portion of the circumference of the base F L required for a pattern to cover the course F G.

In the same manner the covering for the other portion can be found.

TO COVER A DOME BY THE SECOND METHOD.

Let A B C (Fig 78) be the section of a dome; then the length of a course of covering is obtained as follows:—The length of the course B F is equal to the curve A B, and E G the breadth of it; join E D, and the lines 1, 2, 3, and 4 intersected thereby will be the half breadth (for the vertical B D) of the course at the corresponding lines on B F, through which points a line can be drawn which will give the form of the course required.

Fig 77

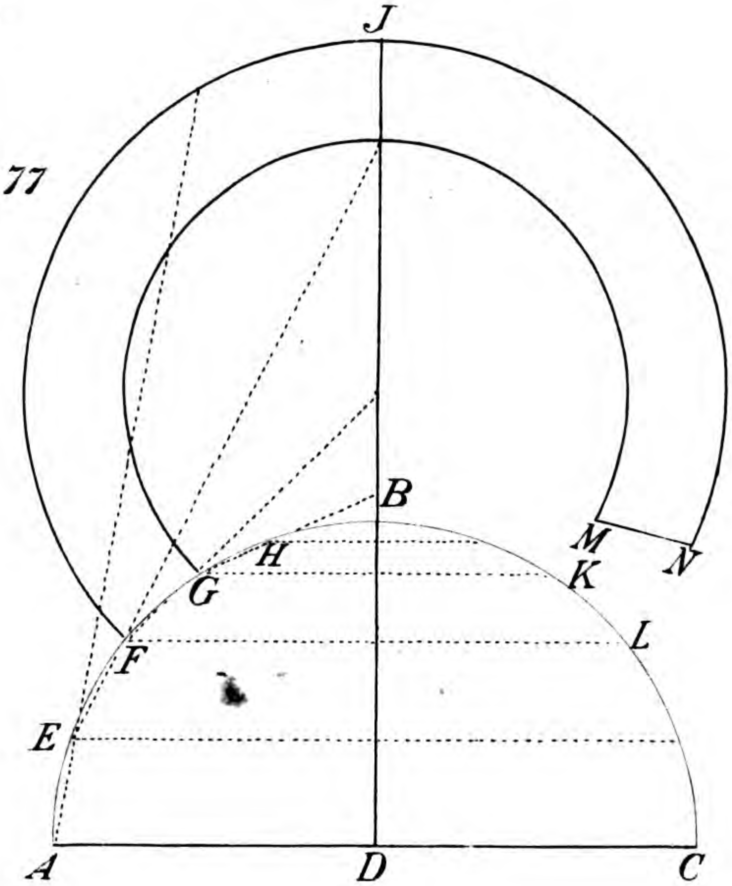


Fig 78

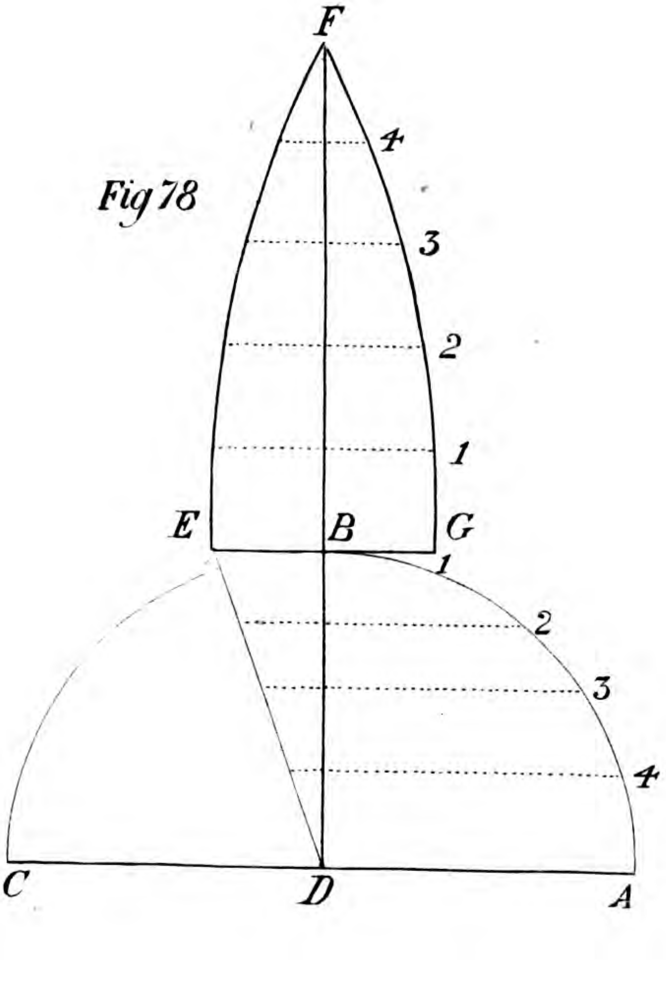


Fig 79

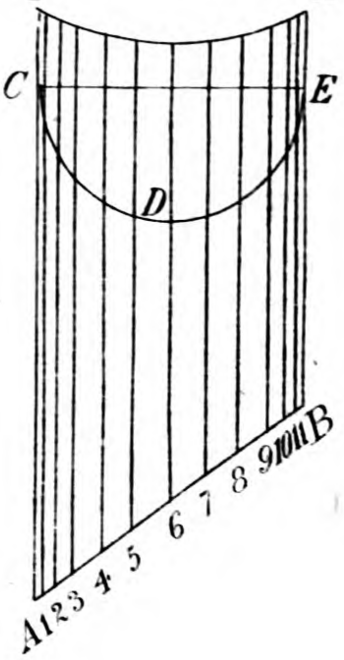
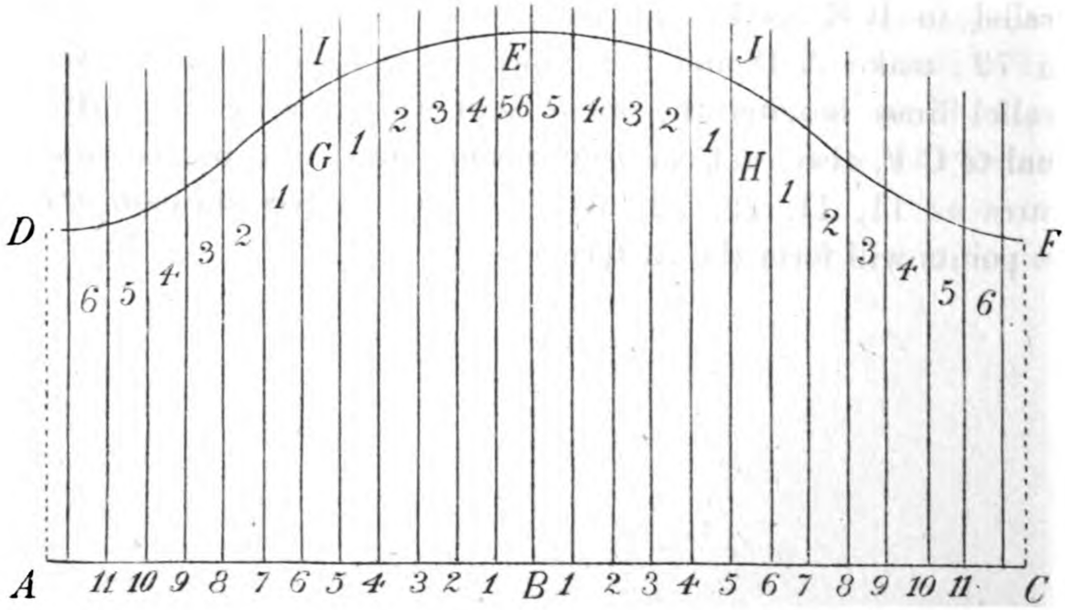

F
H
C
E
D
A 1 2 3 4 5 6 7 8 9 10 11 B

Fig 80


I
E
J
G
H
D
F
1 2 3 4 5 6 5 4 3 2 1
1 2 3 4 5 6
1 2 3 4 5 6
A 11 10 9 8 7 6 5 4 3 2 1 B 1 2 3 4 5 6 7 8 9 10 11 C

TO DESCRIBE A PATTERN FOR A T PIPE; THE CONNECTING PIPE TO BE SMALLER THAN THE MAIN.

Let C E, Fig 79, be the diameter of the collar, and A B the angle required; describe the semi-circle C D E; make C F and E H of equal length, with a radii equal to one-half the diameter of the large pipe; describe the arc F H; divide the semi-circle into any equal number of parts; from the points draw lines parallel to A C, as 1, 2, &c. There must be an odd number of lines, as in the diagram, so that one of the lines run through the centre of the semi-circle.

Set off the line A B C, Fig 80, equal in length to the circumference of the collar C E; erect the lines A D, B E, and C F; set off on each side of B E the same number of equal distances as in the semi-circle, and from the points draw lines parallel to B E, as 11, 22, &c.; make B E equal to A C in Fig. 79; make A D and C F equal to B E, also each of the parallel lines bearing the same figures; make G I and H J equal to C F, also each of the parallel lines bearing the same figures as 11, 11, 22, 22, &c. A line traced through the last points will form the pattern.

PIPES.—TO DESCRIBE A PATTERN FOR A T PIPE AT ANY ANGLE.

Draw the line A E, Fig. 81; erect the line A B, the angle required, also the line E D parallel to A B; make B D equal to the diameter of the pipe; describe the semi-circle B C D; draw the line F G parallel to B D; divide the semi-circle into any number of equal parts from the points; draw lines parallel to A B as 1, 2, 3, &c. Set off the line A B C, Fig. 82 equal to the circumference of the pipe; erect the lines A E, B D, and C F at right angles to A C; set off on each side of B D the same number of equal distances, as in the semi-circle B C D, and from the points draw lines parallel to B D, as 11, 22, and 33, &c. Make B D equal to A B, and E A and C F equal to E D; also each of the parallel lines, bearing the same figures as 11, 22, 33, &c. Make G I and H J equal to G D, also each of the lines bearing the same figures as 11, 11, 22, 22, &c.; then a line traced through the points will form the required pattern.

Fig 81

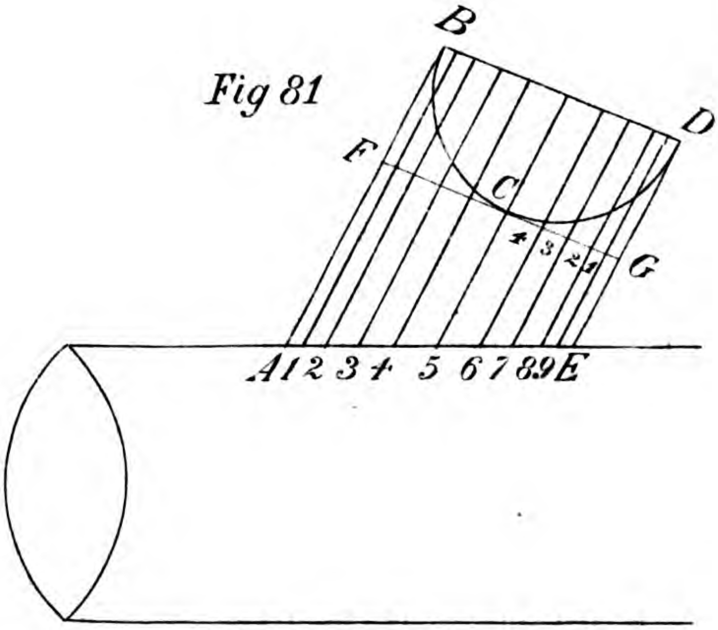
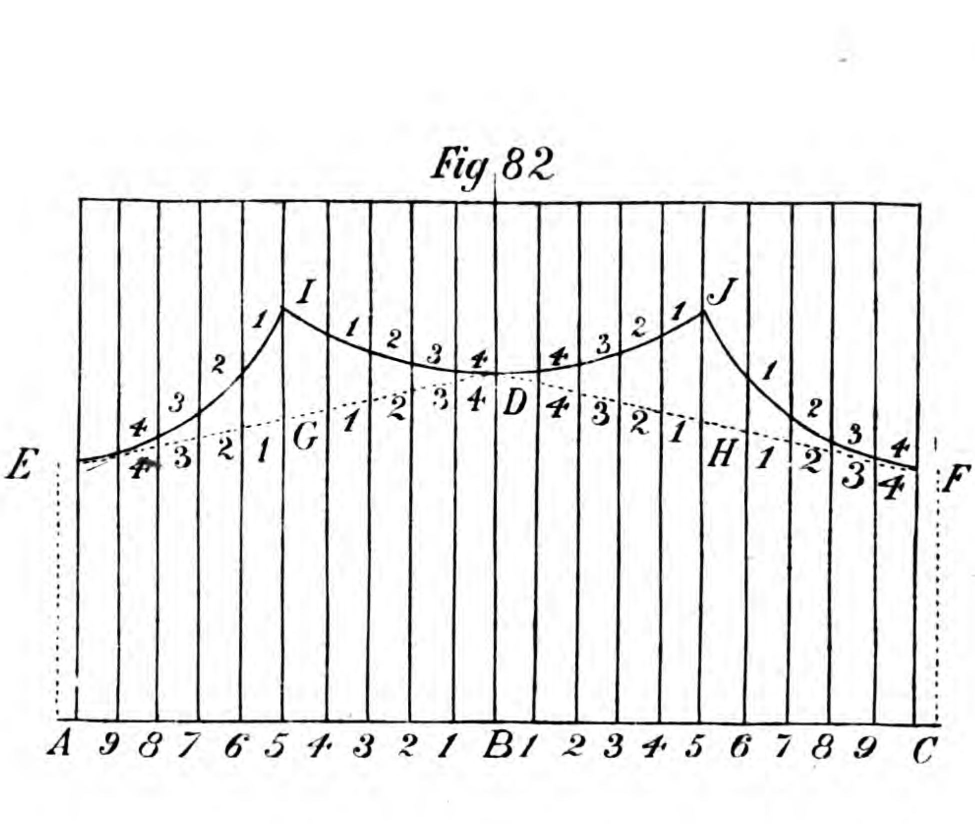

B
D
F
C
4 3 2 1
G
A 1 2 3 4 5 6 7 8 9 E

Fig 82


I
J
1 2 3 4
1 2 3 4 4 3 2 1
1 2 3 4
E
4 3 2 1 G 1 2 3 4 D 4 3 2 1 H 1 2 3 4
F
A 9 8 7 6 5 4 3 2 1 B 1 2 3 4 5 6 7 8 9 C

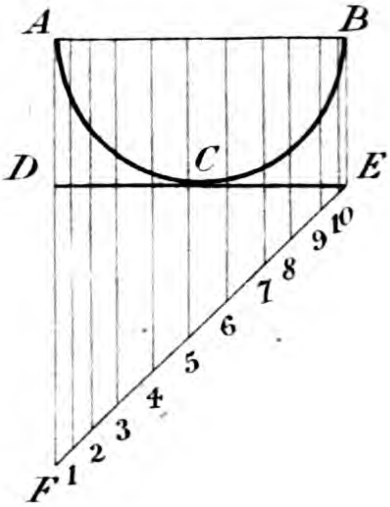


Fig 83

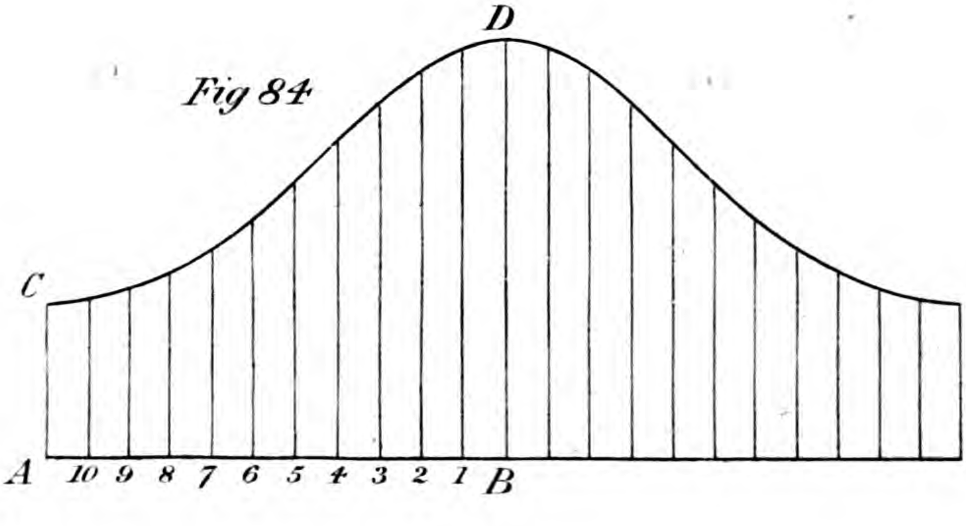


Fig 84

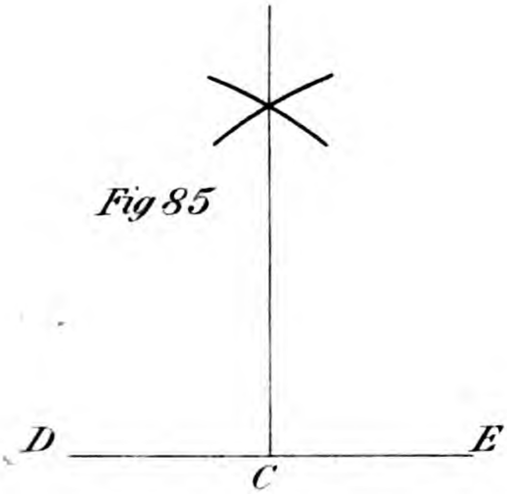


Fig 85

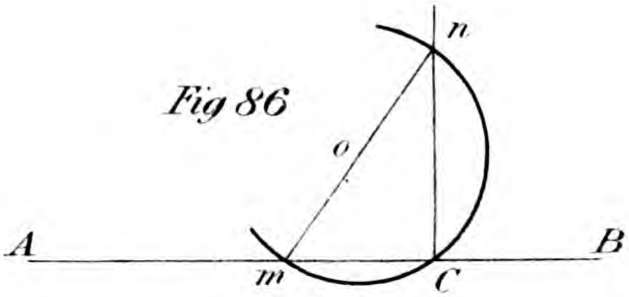


Fig 86

TO DESCRIBE A PATTERN FOR A CONNECTING PIPE AT RIGHT ANGLES.

Make A B equal to the diameter of the pipe (Fig. 83); describe the semi-circle A C B, draw the line A B, draw the lines A F and B E at right angles to A B, draw the line D E parallel to A B, make D F equal to A B, and draw the line F E, divide the semi-circle into any number of equal parts from the points; draw lines parallel to A F, as 1, 2, 3, &c; then set off the line A B (Fig. 84) equal in length to the circumference of the pipe; erect the lines B D and A C at right angles to A B; set off on the line A B (Fig. 84) the same number of equal distances as in the semi-circle from the points; draw lines parallel to B D, as 1, 2, 3, &c.; make B D equal in length to A F (Fig. 83); and A C equal in length to B E; also each of the parallel lines bearing the same figure, as 1, 2, 3, &c., ; then a line traced through the points will form the pattern required.

TO ERECT A PERPENDICULAR ON THE POINT C IN A GIVEN LINE.

Set one foot of the dividers in a given point C (Fig. 85), extend the other foot to any distance at pleasure as to D, and with that extent make the mark D and E, with the dividers one foot in D at any extent above the distance of D and E; describe an arc above the line, and with the same extent, and one foot in E, describe an arc crossing the former; draw a line from the intersection of the arcs to the given point C, which will be perpendicular to the given line in the point C.

TO ERECT A PERPENDICULAR WHEN THE POINT IS AT OR NEAR THE MIDDLE OF THE LINE.

Draw the line A B (Fig. 86), then take any point, o, and with the distance, o C describe the arc m C n, cutting A B in m and C through the centre, O and the point m; draw the line m o n, cutting the arc m C n in n; from the point n draw the line n C, and it will be the perpendicular required.

TO DESCRIBE A PATTERN FOR CONNECTING PIPES AT ANY ANGLE.

Make A C (Fig. 87) equal to the diameter of the pipe, describe the semi-circle A C B, draw the line A C, draw the lines E G and D H, the angle required; draw the line E D, cutting the points E and D; divide the semi-circle into any number of equal parts; from the points draw lines parallel to A E, as 1, 2, 3, &c. Then set off the line A B (Fig. 88) equal in length to the circumference of the pipe; erect the lines A C and B D at right angles to A B; set off on the line A B the same number of equal distances as in the semi-circle A B C; from the points draw lines parallel to B D, as 1, 2, 3, &c. Make B D equal to E A, and A C equal to D C; also each of the parallel lines bearing the same figures as 1, 2, 3, &c.; then a line traced through the points will form the pattern.

Fig 87

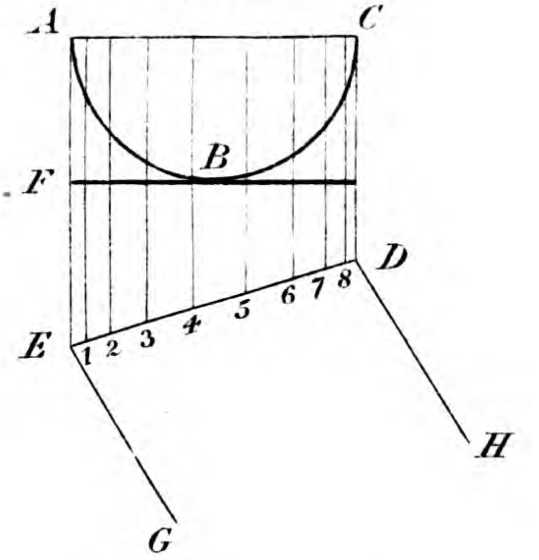
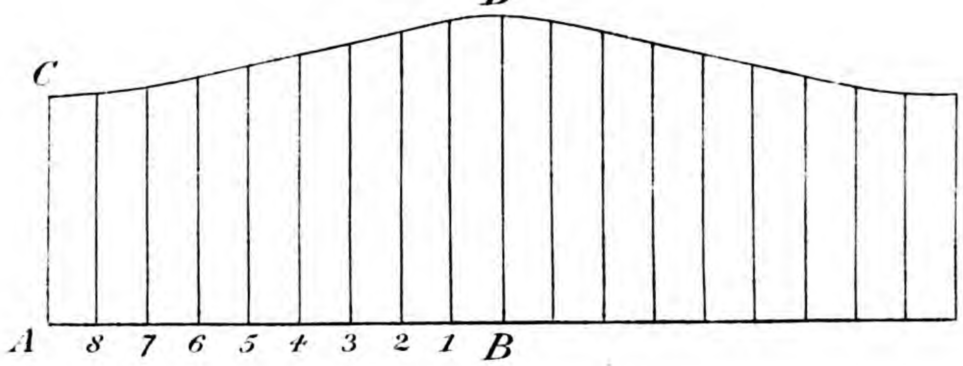


Fig 88



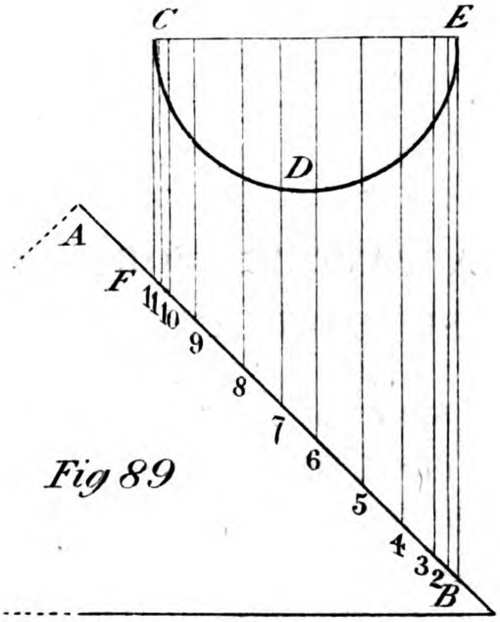
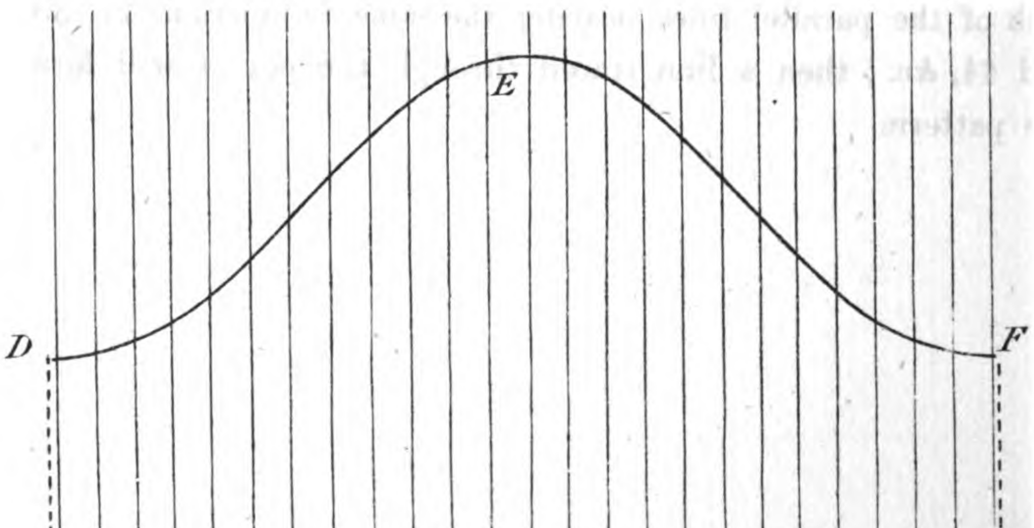

C
E
D
A
F
11
10
9
8
7
6
5
4
3
2
B

Fig 89

Fig 90


E
D
F
A
11
10
9
8
7
6
5
4
3
2
1
B
1
2
3
4
5
6
7
8
9
10
11
C

TO DESCRIBE A PATTERN FOR A PIPE TO FIT A FLAT SURFACE AT ANY ANGLE.

Let A B (Fig. 89) equal the angle; let C E F B equal the pipe, draw the line C E, describe the semi-circle C D E, divide the semi-circle into any number of equal parts; from the points draw lines parallel to E B, as 2, 3, 4, &c. Then set off the line A B C (Fig. 90) equal in length to the circumference of the cylinder C E; erect the perpendicular lines A D, B E, and C F; set off on each side of B E the same number of equal distances as in the semi-circle C D E; from the points draw lines parallel to B E; make B E (Fig. 90) equal to B E (Fig. 89); make A D and C F equal to F C; also each of the parallel lines bearing the same numbers as 22, 33, and 44, &c.; then a line traced through the points will form the pattern.

TO DESCRIBE A PATTERN FOR A T PIPE AT ANY ANGLE, THE COLLAR TO SET ON ONE SIDE OF THE MAIN PIPE.

Let the circle F E (Fig. 91) equal large pipe or boiler make A B equal to the diameter of the collar or branch pipe, B E the angle required; describe the semi-circle A C B; divide the semi-circle into any number of equal parts, from the points draw lines parallel to B E, as 1, 2, 3, &c.

Set off the line A B C (Fig. 92) equal in length to the circumference of the collar A B; erect the perpendicular lines A D, B E, and C H, set off on each side of B E the same number of equal distances, as in the semi-circle A C B; from the points draw lines parallel to B E; make B E equal to E B; make A D and C F equal to D A; also each of the parallel lines bearing the same figures as 11, 22, 33, &c., then a line traced through the points will form the pattern.

Fig 91

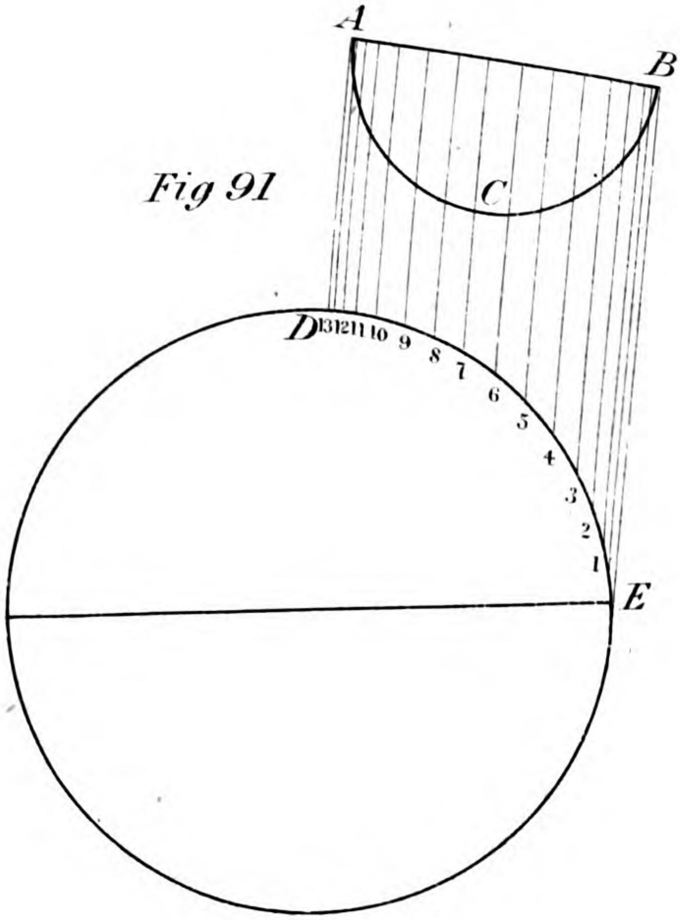

A
B
C
D
13
12
11
10
9
8
7
6
5
4
3
2
1
E
F

Fig 92

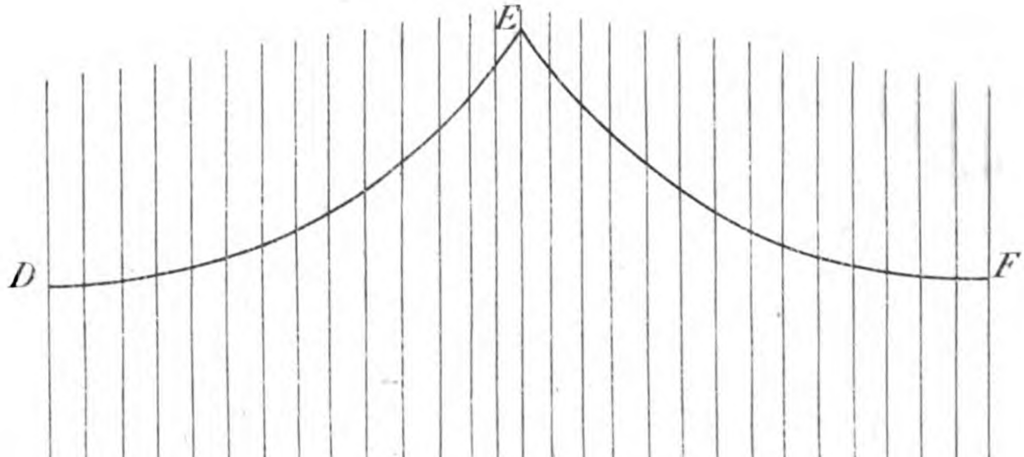

E
D
F
A
13
12
11
10
9
8
7
6
5
4
3
2
1
B
1
2
3
4
5
6
7
8
9
10
11
12
13
C

Fig 93

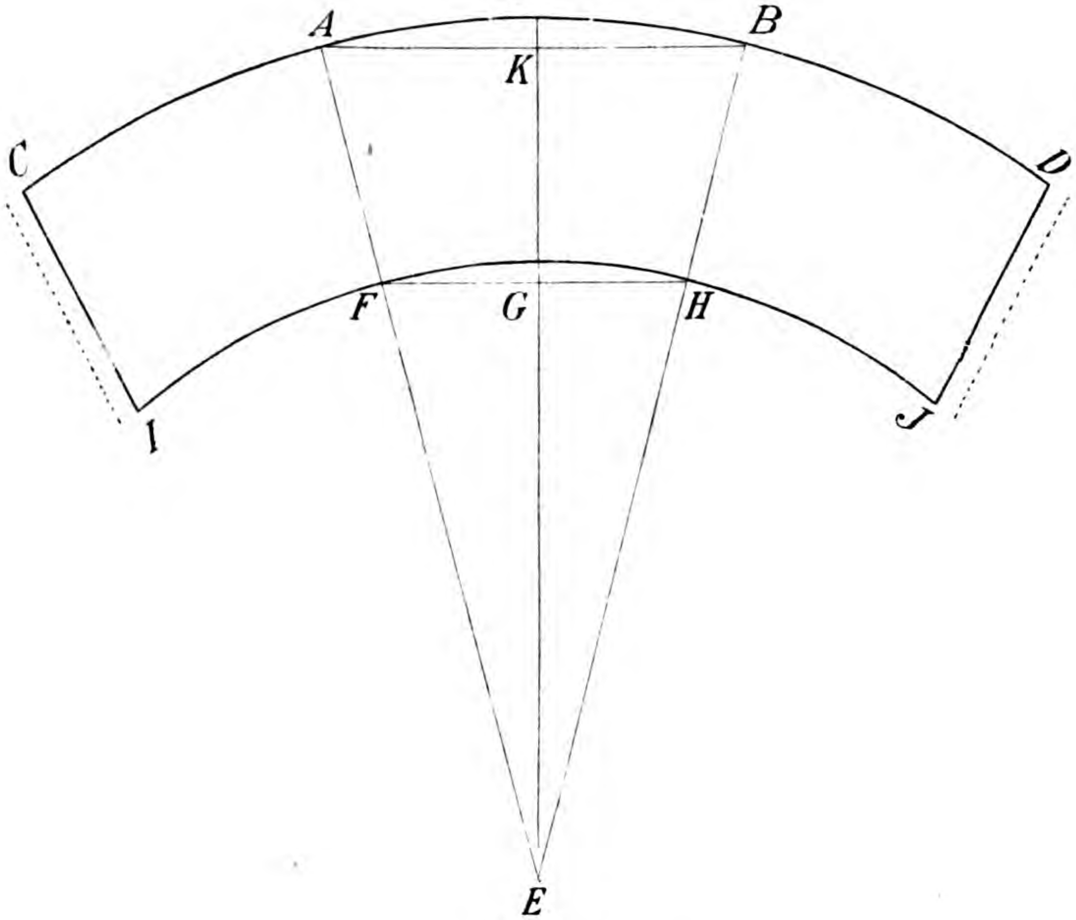
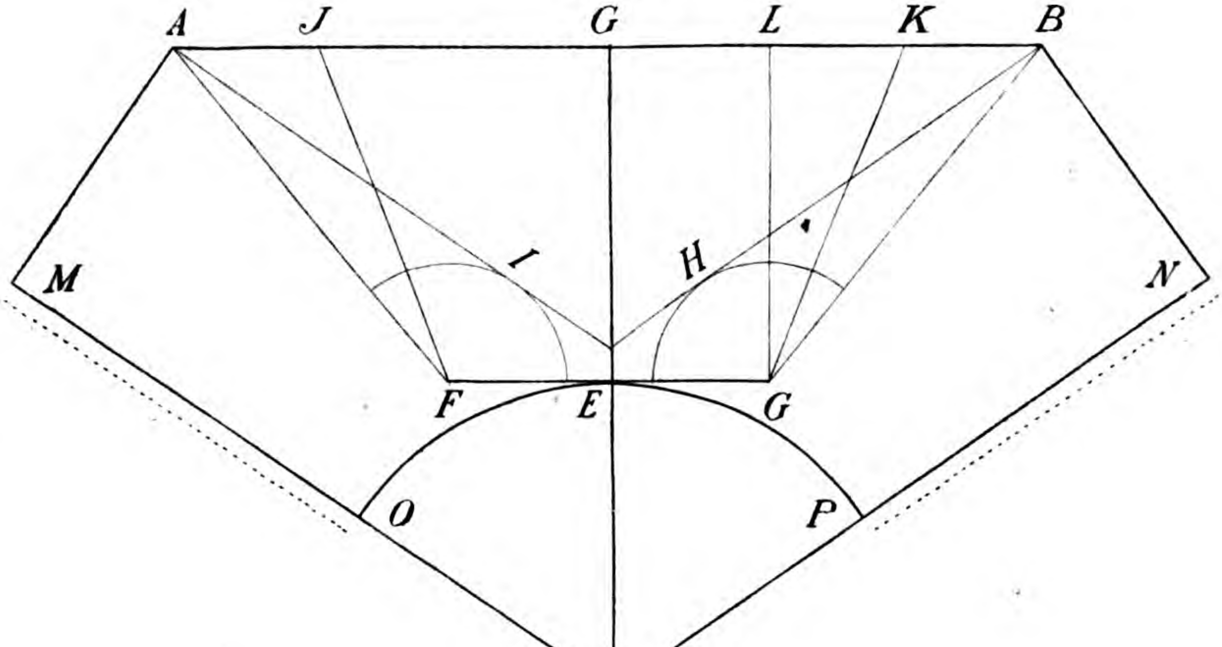


Fig 94



TO DESCRIBE A FRUSTRUM OF A CONE.

Let A B (Fig. 93) equal diameter of large end, F H diameter of small end, G K altitude. Produce A F and B H until they meet at E, with E as a centre, and the radii E F and E A; describe the arcs C D and I J; set off C D equal to that portion of the circumference of A B required for a pattern; draw the lines C I and D J, cutting the centre at E.

Edges for folding or lapping to be allowed, drawing the lines parallel to C I and D J, as shown by the dotted lines.

RECTANGLE BASE WITH A CIRCULAR TOP.

To Describe a Pattern for a Tapering Article, the Base to be a Rectangle and the Top a Circle, to be in Two Sections.

Erect the perpendicular line D C (Fig. 94), draw the line A B at right angles to D C; make C E equal to the slant height, and draw the line F G parallel to A B; make A B equal in length to the longest side of the base; make F G equal in length to one-fourth the circumference of the top, draw the lines A F and B G, make C K equal to one-half the shortest side of the base; erect the line L G parallel to the E C, F and G as centres, with the radii K L; describe the arcs I and H; draw the right angle lines H B N and I A M; set off B M and A M equal in length to C K, and draw the lines M D and N D at right angles to M A and N B, D as a centre with the radii D E, describe the arc O E D.

OVAL.

To Describe a Pattern for a Tapering Oval, or Oblong Article, the Sides to be Straight, with Semi-circle Ends, to be in Two Sections.

Describe the bottom, the length, and breadth required as in Fig. 93, the body as in Figs. 94 and 95.

Describe the right angle A B C (Fig. 94); make B E the altitude, draw the line D E at right angle to B C; make D G equal to A B in Fig. 93; make A B equal to D E and the taper required on a side; draw a line cutting the points A and D and the line B C (Fig. 95); make A C and B D equal to Fig. 94.

Make A B and C D equal to D C in Fig 93; draw the lines C I and D J (Fig. 94), with the radii C D and in Fig. 95, A and B as centres; cut the lines C I and D J, as at I and J, with I and J as centres, describe the arcs A H and B F; also the arcs C G and D E; set off A H and B F equal to C B in Fig. 93; draw the lines G H and E F, cutting the centre at I and J.

The taper to be equal on all sides. In a large article it may be more convenient to lay out the end pieces to fit the semi-circles and join them to the sides, as at D and C in Fig. 93.

Fig 95

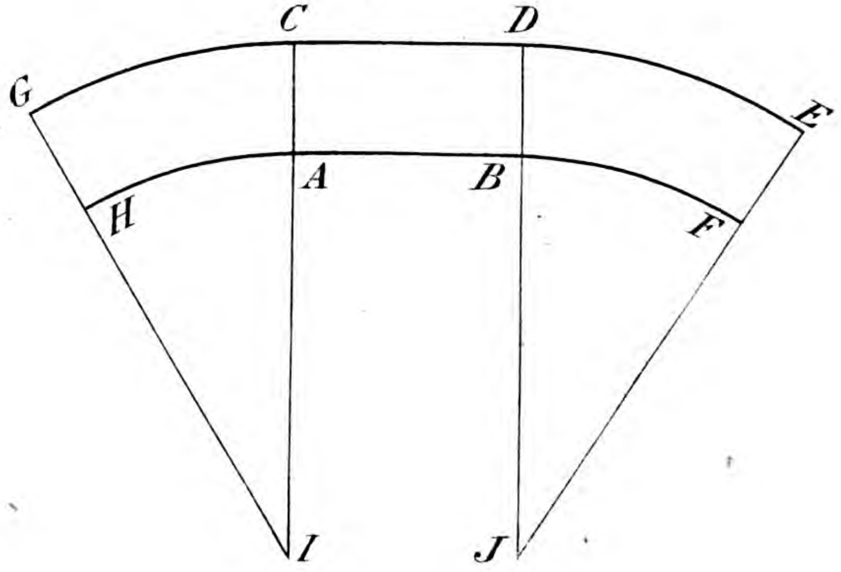


Fig 94

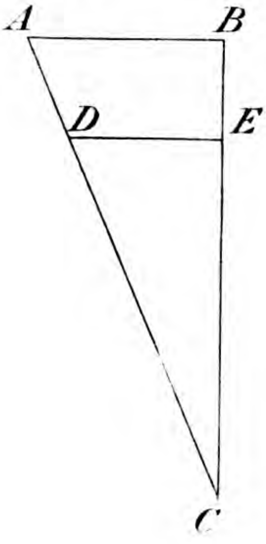


Fig 93

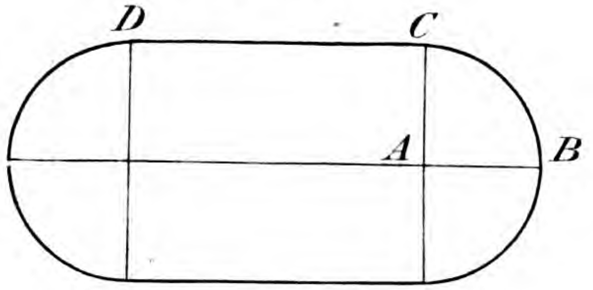
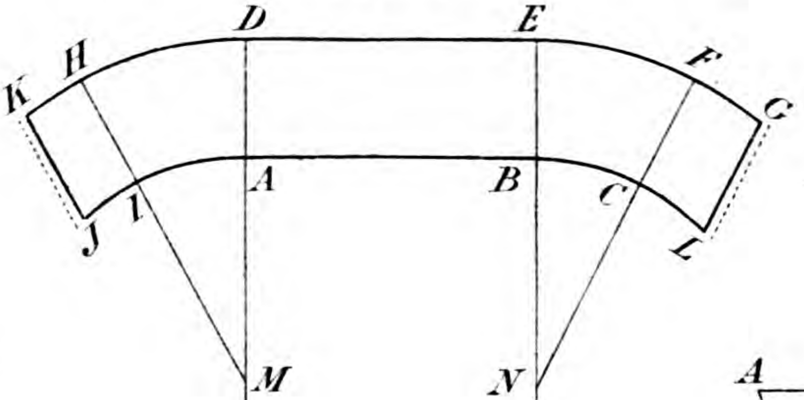


Fig 98



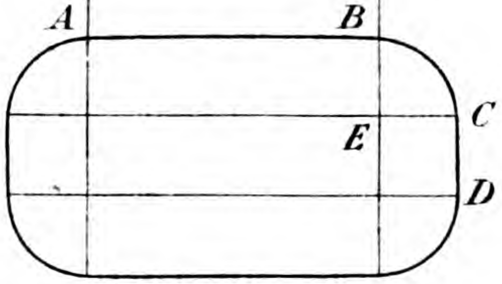


Fig 96

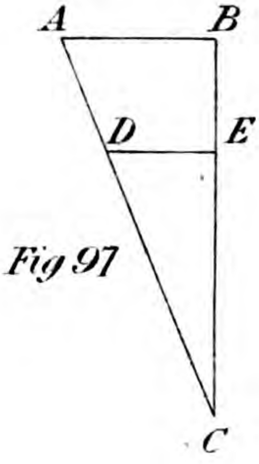


Fig 97

OVAL.

To Describe a Pattern for a Tapering Oval, or Oblong Article, the Sides to be Straight with Quarter-circle Corners, to be in Two Sections.

Describe the bottom, the length and breath required, as in Fig. 96; the body as in Fig. 97 and 98; describe the right angle A B C (Fig. 97); make B E the altitude, draw the line D E at right angles to B C; make D E equal to E C in Fig. 96; make A B equal to D E and the taper required on a side; draw a line cutting the points A and D and the line B C.

Fig. 98, make A D and B E equal to A D in Fig. 97; make A B equal to A B in Fig. 96; draw the lines D M and E N (Fig. 97), with radii C D, and in Fig. 98, A and B as centres; cut the lines D M and E N, as at M and N, with M and N as centres; describe the arcs B C and A I; also the arcs E F and D H; set off B C and A I equal to B C in Fig 96; draw the lines H I and F C, cutting the centres M and N. Draw the lines F G and C L at right angles to F N; also the lines K H and J I at right angles to H M; make C L and J I equal to one-half of C D in Fig. 96; draw the lines K J and G L at right angles to K H and F G.

The taper to be equal on all sides.

RECTANGLE BASE WITH A SQUARE TOP.

To Describe a Pattern for a Tapering Article, the Base to be a Rectangle and the Top Square, to be in two Sections.

Erect the perpendicular line K C, Fig. 99; draw the line A B at right angles to K C; make K C equal to the slant height, and draw the line D E parallel to A B; make A B equal in length to the longest side of the base; make D E equal in length to one side of the top; draw the lines A D and B E; make C G equal to one-half the shortest side of the base, D and E as centres, with a radii equal to one-half the top and the shortest side of the base, as from G to F; describe the arcs J and I; draw the right angle lines J A L and I B M; set off A L and B M equal in length to C G, and draw the lines M N and L O at right angles to B M and L A; also the lines N E and O D at right angles to N M and O L.

Fig 99

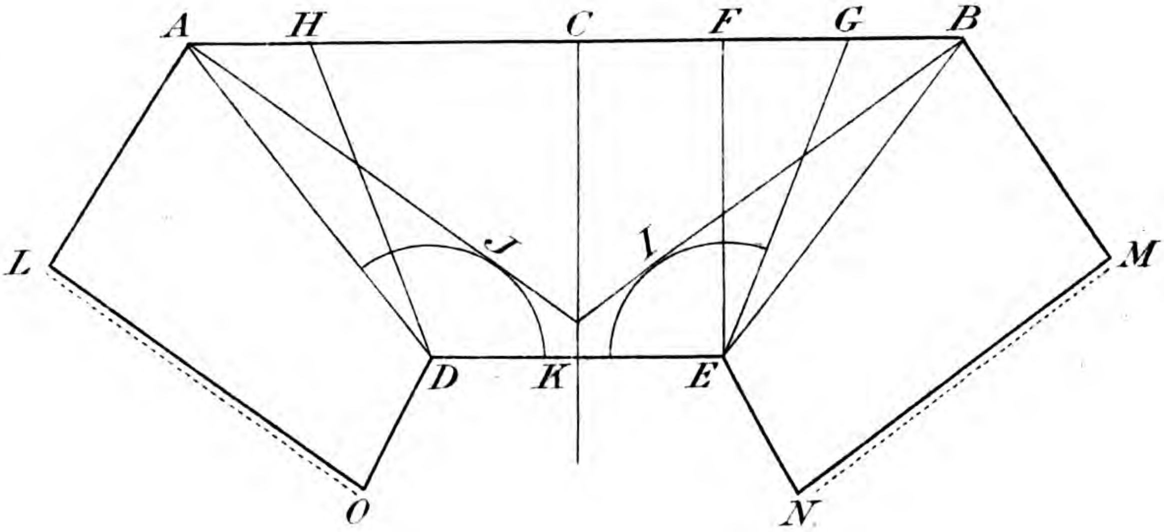
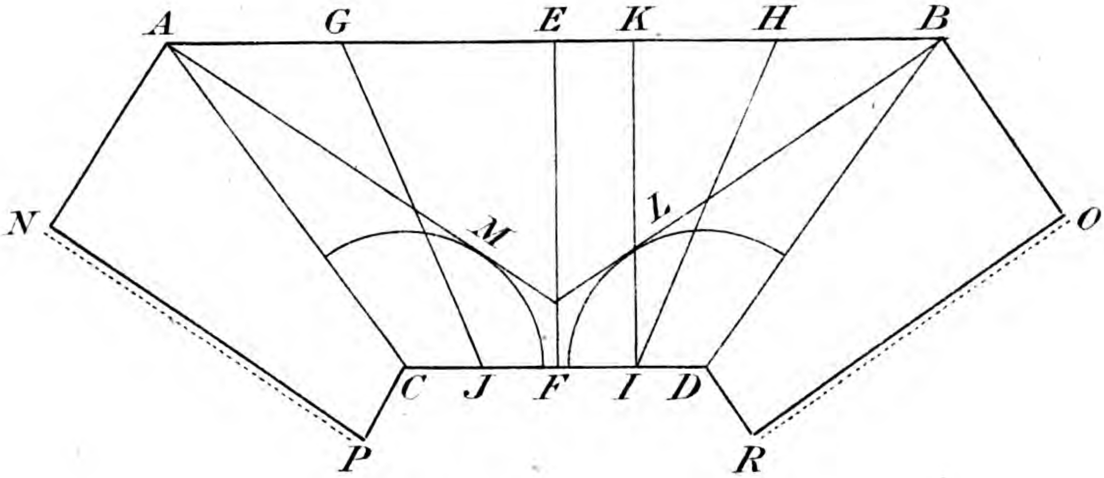


Fig 100



RECTANGLE.

TO DESCRIBE A PATTERN, FOR A TAPERING ARTICLE, THE TOP AND BASE TO BE A RECTANGLE, TO BE IN TWO SECTIONS.

Erect the perpendicular line F E (Fig. 100) ; draw the line A B at right angles to F E ; make F E equal to the slant height of the article and draw the line C D parallel to A B ; make A B equal in length to the longest side of the top ; draw the lines A C and B D ; make G H equal in length to the shortest side of the top ; draw the line H I ; also erect the line K I parallel to F E, C and D as centres, with the radii H K ; describe the arcs M and L, draw the right angle lines L B O and M A N ; set off B O and A N equal in length to E H, and draw the lines O R and N P at right angles to O B and N A ; also the lines R D and P C at right angles to R O and I N.

SQUARE BASE WITH A CIRCULAR TOP.

Erect the perpendicular line N F (Fig. 101), draw the line B at right angles to N F, make E F equal to the slant height, and draw the line C D parallel to A B; make A B equal in length to one side of the base; make C D in length to one-fourth of the top, and draw the lines A C and B D, C and D as centres, with a radii equal to one-half the difference of the two ends; describe the arcs I and H, draw the right angle lines I A J and H B K, set off J A and K B equal to F B, and draw the lines J N and K N at right angles to J A and K B, N as a centre with the radii N E describe the arc L E M.

SQUARE.

To Describe a Pattern for a Square Tapering Article to be in Two Sections.

Erect the perpendicular line E F (Fig, 102) equal to the slant height of the articles; draw the line A B at right angles to E F, draw the line C D parallel to A B, make A B equal in length to one side of the base; make C D equal in length to one side of the top or smallest end; draw the lines A C and B D, C and D as centres, with a radii equal to one-half the difference of the two ends, as from B to G; describe the arcs I and H; draw the right angle lines I A J and H B K; set off J A and K B equal to F B, and draw the lines J L and K M at right angles to J A and K B; also the lines L C and M D at right angles to L J and M K.

Fig 101

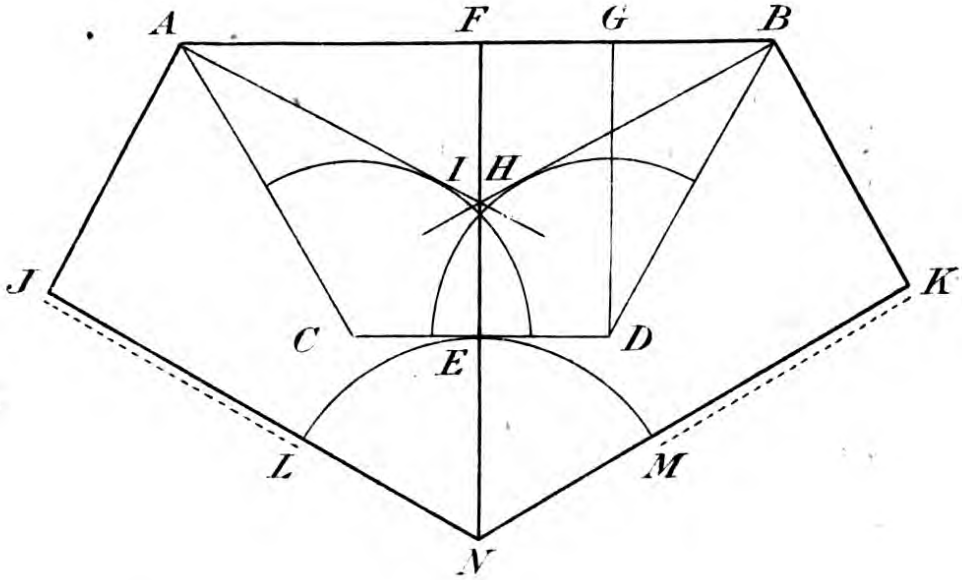


Fig 102

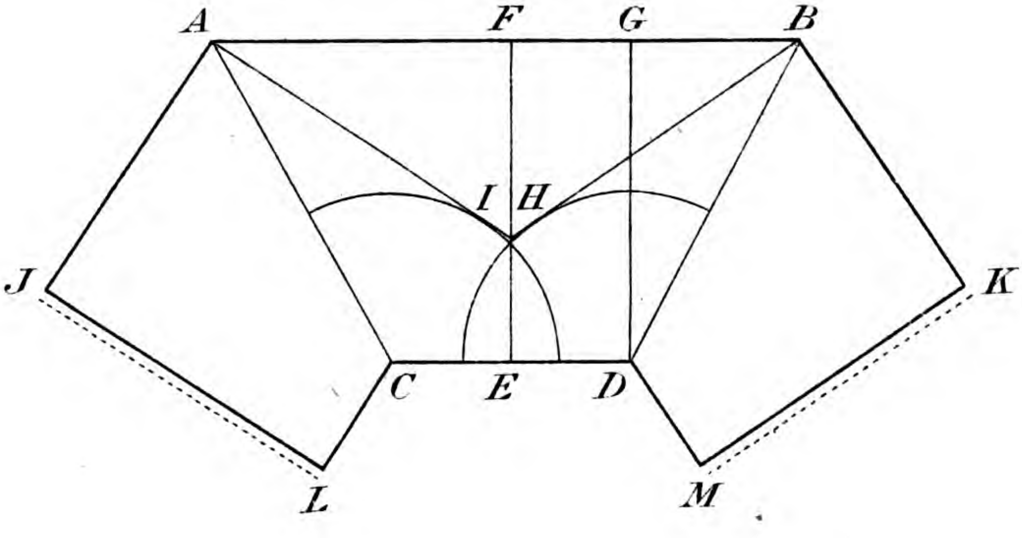


Fig 103

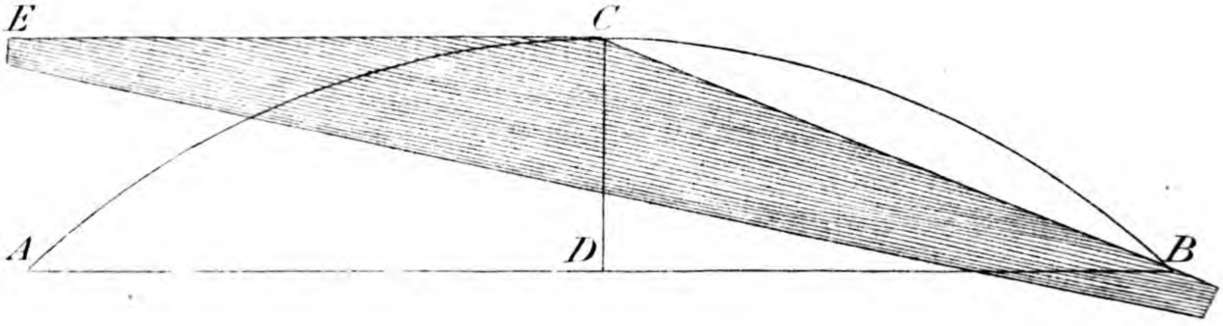


Fig 104

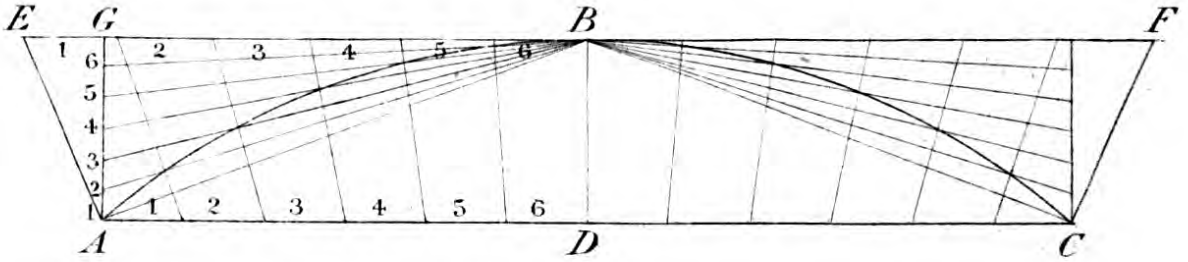


Fig 105

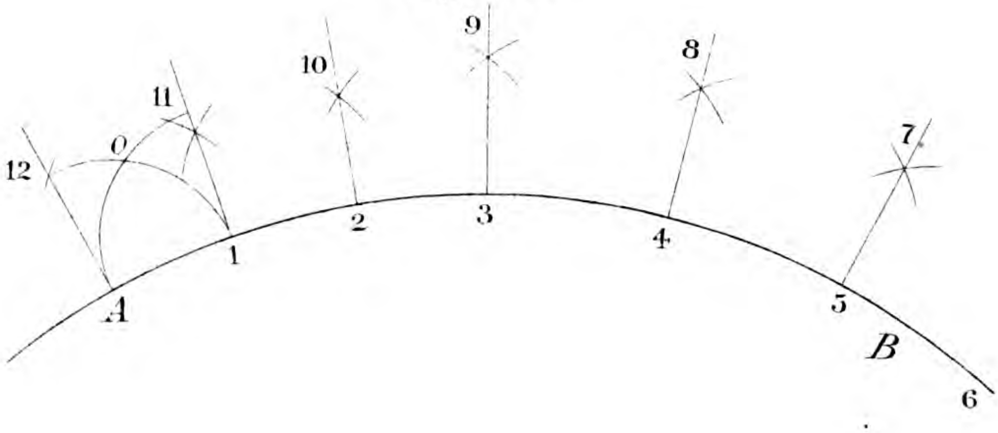


FIG. 103.—TO STRIKE A SEGMENT (OR PART OF A CIRCLE) BY A TRIANGULAR GUIDE, THE CHORD AND HEIGHT BEING GIVEN.

Let A B be the chord of the segment and D C the height (or versed sine), join B C and cut C E parallel to A B, and make it equal to B C; fix a pin in B and another in C, and with the triangle E C B describe the curve C B; then remove the pin B to A, and by guiding the sides of the triangle against A C strike the other part of the curve A C B.

FIG. 104.—THE CHORD AND HEIGHT OF A SEGMENT OF A CIRCLE OF LARGE RADIUS BEING GIVEN, TO FIND THE CURVE WITHOUT HAVING RECOURSE TO THE CENTRE, WHICH IS SUPPOSED TO BE UNATTAINABLE.

Let A C be the chord line and D B the height, through B draw E F parallel to A C, join A B and B C, draw A E at right angles to A B and C F at right angles to B C; divide A D and E B into any number of equal parts (say 6); join the corresponding number 11, 22, 33, &c. Also divide A G into the same number of equal parts, and from each division draw lines to B, and the points of intersection will be points in the curves.

FIG. 105.—HAVING AN ARC OF A CIRCLE GIVEN, TO RAISE PERPENDICULARS FRON ANY POINT OR POINTS WITHOUT FINDING THE CENTRE.

Let A B be the given curve or arc, and A 1, 2, 3, 4, 5 the points from which perpendiculars are to be erected; in the space 5 B make the point 6 equal to 45, from 4 and 6 as centres, with a radius greater than half the distance between them; describe arcs intersecting each other at 7; a line drawn at the point of intersection at 7 to 5 gives one of the perpendiculars required; the other points as far as 11 will be found in the same manner. If a perpendicular is to be raised at A, the extremity of the curve, a method somewhat different must be employed. Suppose the perpendicular I 11 to be erected, from I with the radius I A describe the curve A 11, and from A with the same distance describe 12 I, make o 12 equal o 11 and join A 12, will give the perpendicular wanted.

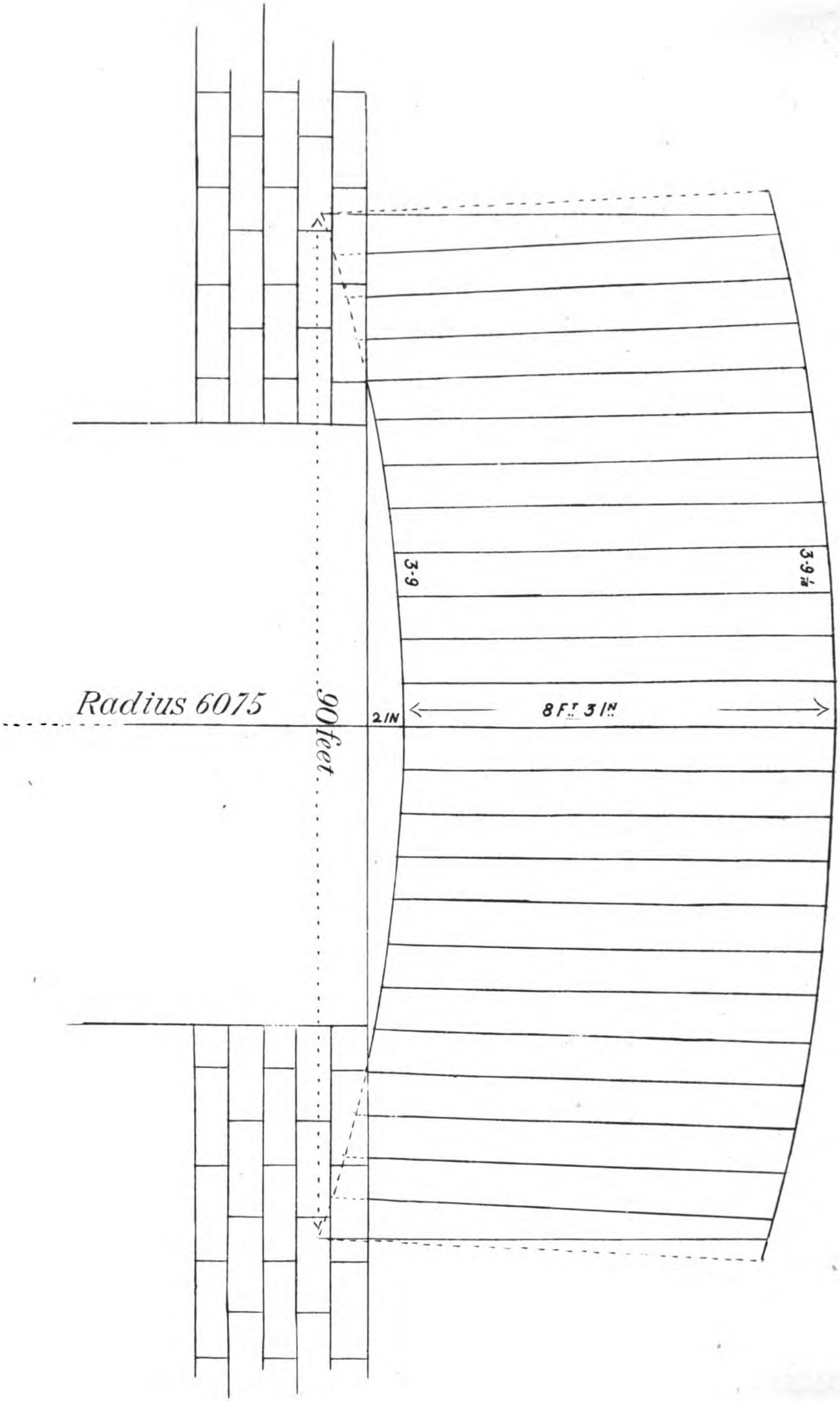


Fig 106

How to put the Camber into Girders.

Rule.—Multiply the depth of the girder in 64ths by the length of girder in feet, and divide quotient last found by the radius in feet, the remainder, divided by the number of web plates in the girder, will give the taper in each web plate.

Example.—Let us suppose we have a girder to make 90 ft. long, 8′ 3″, with 24 webs, 3′ 9″ wide, to camber 2″.

8′ 3″ depth of girder

12

99

64

396

594

6336 = depth of girder in 64ths

90 = length of girder

= To radius in ft. 6075)570240 ($\frac{94}{64}$ (nearly) = 1″ $\frac{7}{16}$ $\frac{1}{32}$

54675

23490

24300

The $\frac{94}{64}$ will of course want dividing into the *top* flange plates and angle-irons.

Note.—The dotted lines show the shape of girder if carried out, but the end web plates are cut as the lines show, so that the girder shall be plumb also to rest level on the abutment.

RULE FOR FINDING RADIUS.

Square half the length of girder, divide by the camber, then add the camber, which will give the diameter; divide by 2, and you will have the radius.

45 half-length of girder
12

540
540

21600
2700

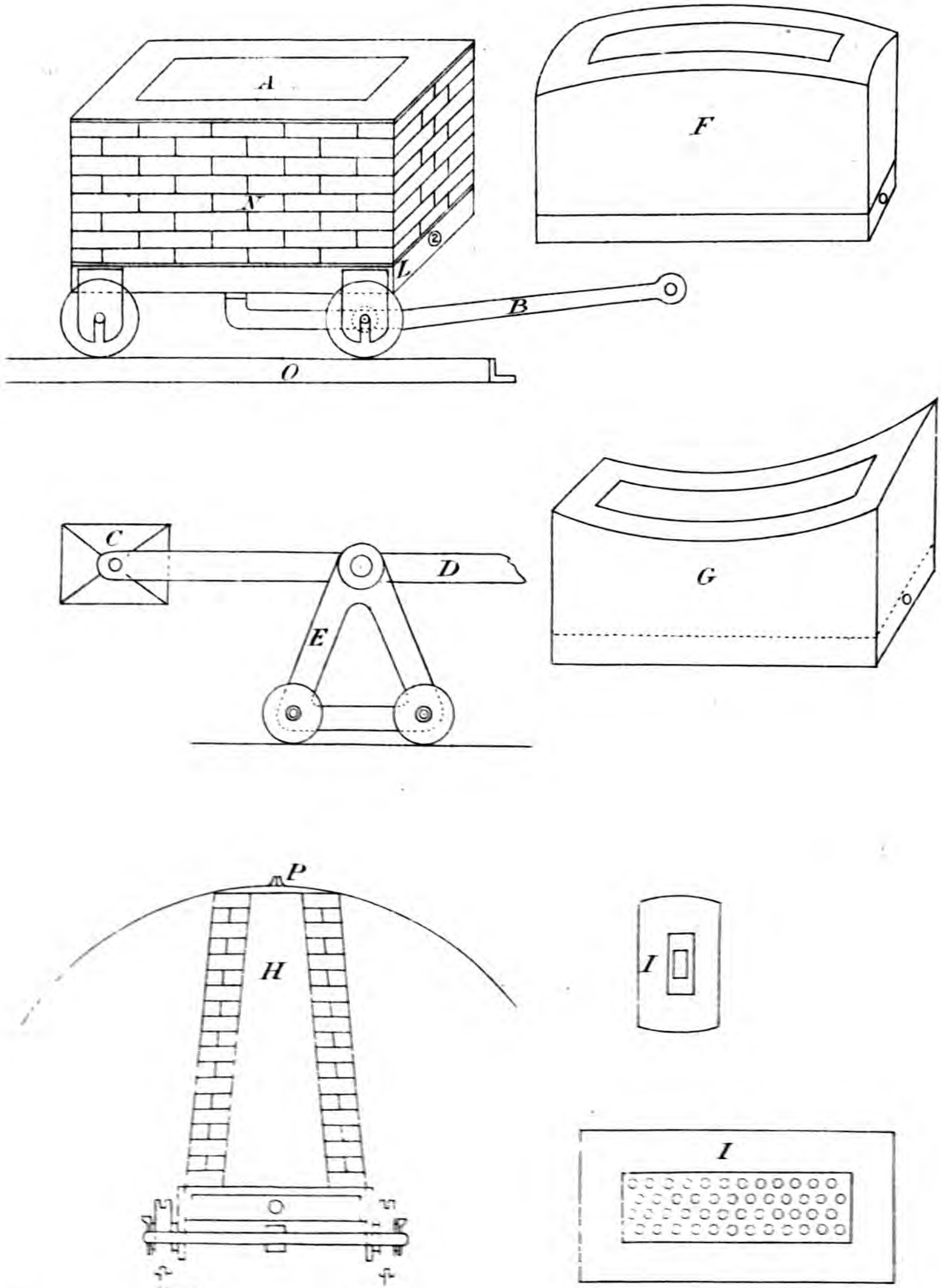
2″)291600

145800
2 = camber
2)145802 = diameter in inches

12)72901 = radius in inches

$6075\frac{1}{12}$ = ,, in feet

By this method (which is the only correct one) of putting the camber in, the web plates can be planed to their proper size, so that all the joints shall be good, and the correct amount of camber in the girder.


A
N
②
L
B
O
F
C
D
E
G
P
H
O
O
I
I

PORTABLE FIRES.

A, portable fire, with false bottom perforated with holes to admit the blast in the bottom of the fire, can be made to any shape or dimension to suit the work to be done. B, the lever to lift the fire to the work, as shown at P. The lever forms a joint on the front axle-tree and extends to the centre of the bottom, and when the man weighs down lifts the fire up to the plate and leaves the axle-tree on the line. C, the hammer, which works on a pin to allow it to adjust itself. D, the lever, made to any length required. E, the stand which carries the hammer, on wheels, to suit the same lines as the fire, as shown, O. I, end view of hammer, a cast metal block, say 16 in. × 9 in. × 8 in., the face to any radius required. F and G, flanging fires to any radius. I, perforated plate for bottom. L, space between bottoms. The circular hole is to admit blast.

These fires are simply a few old boiler plates put together in any shape, round, square, or oval, as the work to be done may require, and lined inside with fire-bricks. They should be wide at the bottom and tapering at the top, so that they may be regulated to any length of a heat desired. Hard coke must be used in these fires, and you must have good blast.

UPON A GIVEN LINE, A B, TO DESCRIBE A SQUARE.

From the point B (Fig. 107) draw B C perpendicular, and equal to A B; on A and C, with the radius A B, describe two arcs cutting each other in D; draw the lines A D, D C, and the figures A B C D will be the square described.

TO FIND THE CENTRE OF A CIRCLE.

Draw any chord A B (Fig. 108) and bisect it by a perpendicular C D, which will be a diameter of the circle. Bisect C D in E, then E is the centre of the circle.

UPON A GIVEN RIGHT LINE, A B, TO MAKE AN EQUILATERAL TRIANGLE.

From the points A and B (Fig. 109), with a radius equal to A B, describe arcs cutting in C; draw the lines A C, and the figure A C B will be the triangle required.

TO DESCRIBE AN ELLIPSE.

Draw the lines A B C D (Fig. 110) at right angles to each other; divide A B into four equal parts; and from centres 1 2, with radius A 1 or B 2, draw circles touching each other at E; from point C, with radius C 4 or C 5, draw the arc 4 D 5; and with the same radius, with point D as a centre, describe the arc 6 C 7. The diagonals 4 C, 5 C, 6 D, 7 D, are terminals or points where the arcs intersect or cut each other.

Draw the lines A B C D (Fig. 111) at right angles to each other; divide A B into three equal parts, as E F B; also

Fig 107

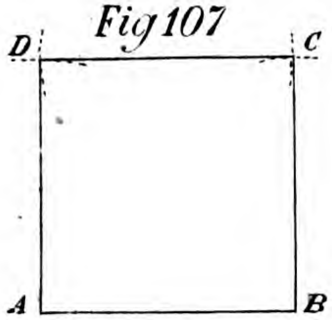


Fig 108

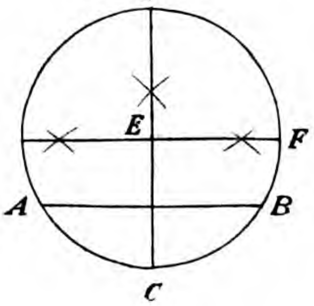


Fig 109

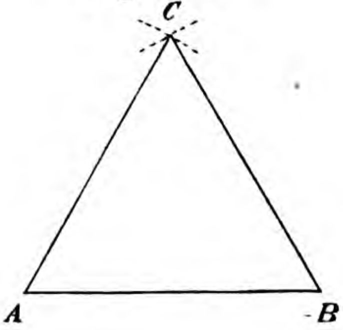


Fig 110

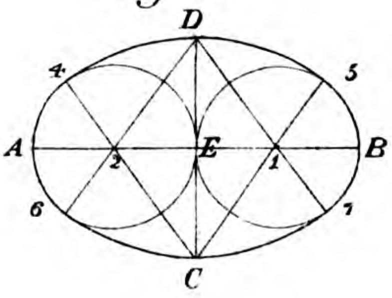


Fig 111

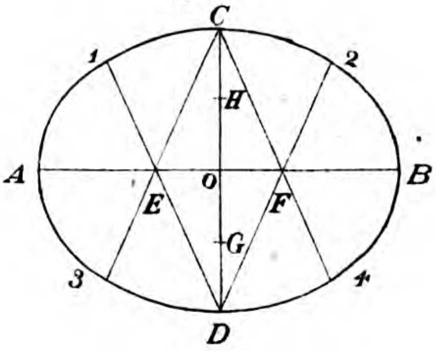
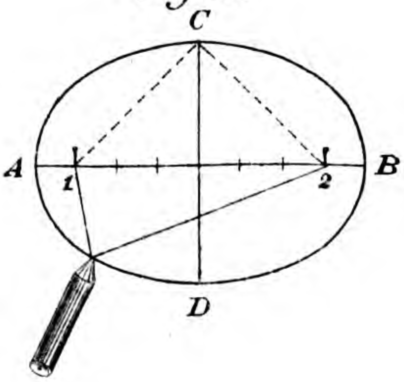


Fig 112



the line C D into four equal parts, as G O H C. From points E F as centres, with radius E A, draw the arcs 1 A 3, 2 B 4; and from points G H as centres, with radius G 1, describe the arcs 1 C 2, 3 D 4. The diagonals are the terminals.

First mark out the length and breadth of the figure, as A B C D (Fig. 112); divide the major axis A B into eight equal parts, as shown; now fix two pins at the division 1 2, next fasten two ends of a string so that it will stride the pins on the line A B, the loop extending to point D or C, fix a pencil or scriber in the loop of the string; by stretching the string with the pencil point touching D, and carrying it gently round, a perfect ellipse will be formed.

THE PRINCIPAL MOVING POWERS.

These are the strength of man and animals, wind, water, steam, weights, springs, and magnetism.

MAN.

The ordinary strength of a man is estimated at the one-fifth of that of a horse; that is, the strength of five men are equal to that of one good horse, and can accomplish as much work.

Man can exert the greatest strength in pulling upwards from about the height of his knees, and the least when he pushes from him horizontally about his own height.

In dragging a barge along a river, having a rope over his shoulders, a man does not perform more than the twenty-seventh of the strength of a horse.

In turning a winch a man's power varies at different points of pulling up and pushing from him, but if he is able to work a day drawing up a weight of thirty pounds, by fixing a winch in an opposite direction, and placing another man at it, the two will with equal ease rise seventy pounds, because at the weakest point of one man the other is strongest, and by this equalisation the advantage of ten pounds is gained.

In carrying weights upon the shoulders the strength of man exceeds that of a horse, as a dock labourer will carry 200 pounds at the rate of three miles an hour. With a weight of 300 pounds on elastic poles slung from the shoulders, as the old chairmen, two men will walk at the rate of four miles an hour.

A HORSE.

A horse can draw 200 pounds over a pully eight hours a day, two and a half miles an hour. If the weight be 240 pounds he can only work six hours a day, and slower. In turning a mill a horse exerts its strength to the best advantage in a circle of forty feet; if reduced one-half he has two-fifths less power.

A horse has the least power in ascending a hill. Three men will accomplish much more than a horse in such a case.

The greatest power of a horse is in drawing in a straight line, a position in which man loses strength, one horse being equal to twenty-seven men.

WIND.

Air in motion is wind, and breathes with a soft force of little more than 1½ feet per second, but in the hurricane rages with destruction in its course, at about 147 feet in the same period of time. Roughly, we may say that a wind moving about 12½ feet per second will strike a surface of a square foot with a force equal to two ounces.

WATER.

The running stream or river, the natural waterfall or roaring cataract, man seizes and makes subservient to his uses. They afford a uniformity of motion beyond that of the wind, and, consequently, are in proportion more valuable as a moving power. Water falling from a height of two feet, with a velocity of eleven feet per second, will turn a wheel so as to give motion to a four-feet six-inches diameter millstone at a rate of 120 revolutions in a minute, the wheel moving with a third-part of the velocity of the water.

STEAM.

This is one of the most powerful of the moving agents, as it is capable of the greatest intensity. A cubic inch of water forming into a cubic foot, or 1728 inches, of steam, possesses an elastic force of fifteen pounds on the square inch at a temperature of 212°, at 250° thirty pounds, at 270° forty-five pounds, at 290° sixty-six pounds. A cubic inch of water converted into steam gives a mechanical force capable of raising one ton one foot high. A cubic foot of water made into steam per hour is equal to the power of one horse; that is, 33,000 pounds raised one foot per minute. With such power controlled by man's inventive genius, the many wonders that daily present themselves are achieved.

WEIGHTS.

Weight, or gravity, is another power which is uniform in action. Weights are applied as the motive power of clocks and other machines. Requiring to be wound up, they are only taken into use where the motion is slow.

SPRINGS.

A spring requires time to bend it; as a bow, where a force is concentrated that can in a moment be released to give a rapid blow. Like weights, springs have to be wound up after being expended, and are thus adapted to slow action. A spring is not uniform in its action, having the greatest power when most bent. This peculiarity, where regularity is wanted, as in a watch, requires contrivances to rectify it. This is effected by what is called a fusee. The part on which the chain is wound up by means of the key gradually lessens from the bottom to the top by a spiral line. When the watch is first wound up the fusee is covered to the top by the chain, and the newly wound-up spring in the other barrel, being strongest at that time, unwinds it from a short lever, which the top of the fusee represents. Gradually, as the spring loses its power, the lever becomes longer, and thus an equal motion is preserved.

MAGNETISM.

If a bar of soft iron in the form of a horse-shoe or a common door staple be wrapped around with a copper wire, and a current of electricity passed through the wire, the iron becomes a most powerful magnet, called an electro-magnet, and may be constructed so as to bear the weight of many tons. With this power, by making some magnets moveable and others fixed, an attraction and repulsion has been created with such intensity as to act as a great moving power, giving motion to large engines.

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Blake & Mackenzie, Printers, School Lane, Liverpool.