LAYING DOWN AND TAKING OFF

By

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NAVAL ARCHITECTURE SIMPLIFIED

and

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Introduction

THIS book was written for the purpose of explaining to men who are not familiar with such work as laying down the lines of a vessel in a Mould Loft of a Shipyard or Boatbuilding plant. It shows how the lines of a vessel are enlarged to full size and the correct shapes of all the timbers that compose the frame obtained.

A serious and ambitious worker who desires to advance and will give one hour a day for a limited time, will find a wealth of information in this book that he can readily grasp and retain through life.

CHARLES DESMOND.

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Laying Down and Taking Off

Chapter I

1a. Laying Down a Small Wooden Vessel

A designer expresses his ideas of shape and construction by means of drawings and written specifications, the drawings being made to scale (smaller than full size) and in sufficient detail to convey to the builder all necessary information about shape and construction. When a set of boat or vessel drawings is received by a builder, he enlarges the *lines* drawing to full size. This is called *"laying down"* and when this is done the principal construction details are enlarged to full size, and necessary full-sized templates, moulds and patterns are made for the builders. This work is called *"taking off"*.

Laying Down and Taking Off work is done on the floor of a well-lighted room called a mould loft. This floor is usually sufficiently wide and long to "lay down" the largest sized vessel that will be built in yard. Nearly every shipyard has its mould loft, the majority being constructed in such a manner that the entire floor is free from posts and obstructions, light being admitted on all sides and from overhead.

As I desire to make my explanation perfectly clear to men not familiar with work done in a mould loft, I will first describe and illustrate the work of "laying down" a small commercial vessel to be constructed of wood and afterwards explain the work of "laying down" a vessel to be built of steel.

Fig. 1 illustrates the scale lines drawing and Figs. 2 and 3 construction drawings of wood-constructed vessel I am going to "lay down".

1a[1]. Explanation of Figures in Circles on No. 1 Illustration

Figures marked in circles are placed on drawing by me to aid the reader in identifying each line and to explain the order in which the various lines are usually "laid down" by a mould's loftsman. ***They are not a part of a lines drawing.***

List of Numerals in Circles and Name of Each Line

Profile View

1	Base
2	Perpendicular
3	Ordinates
4	Water-line planes
5	Sheer and top of rail
6	Bottom of keel
7	Rabbet
8	Top of deck

Half-Breadth View

9	Rabbet
10	Front of stem
11	Top of rail
12	Sheer
13	L.W.L.
14, 15, 16	W.L. below l.w.l.
17, 18, 19	W.L. above l.w.l.
20	Buttock lines

Body Plan

21	Center line
22	Rabbet
23	Half-width at Stem
24	Cross-section No. 7
25	" " " 6
26	" " " 5
27	" " " 4
28	" " " 3
29	" " " 2
30	" " " 1
31	" " " 8
32	" " " 9
33	" " " 10
34	" " " 11
35	" " " 11½
36	" " " 12
37	Buttocks
38	Diagonals
39	Shaft
40	Shaft line on half-breadth water-line view
41	Shaft line on profile
42	Buttock profile

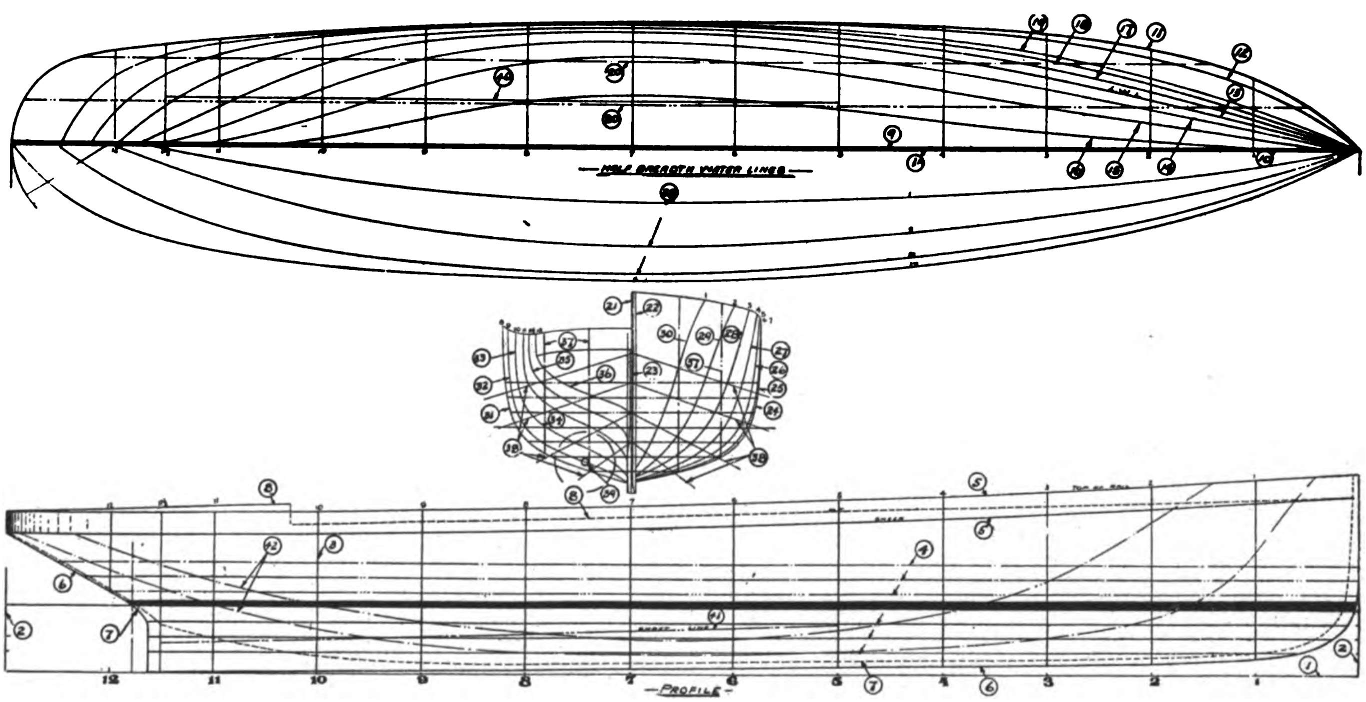


Fig. 1

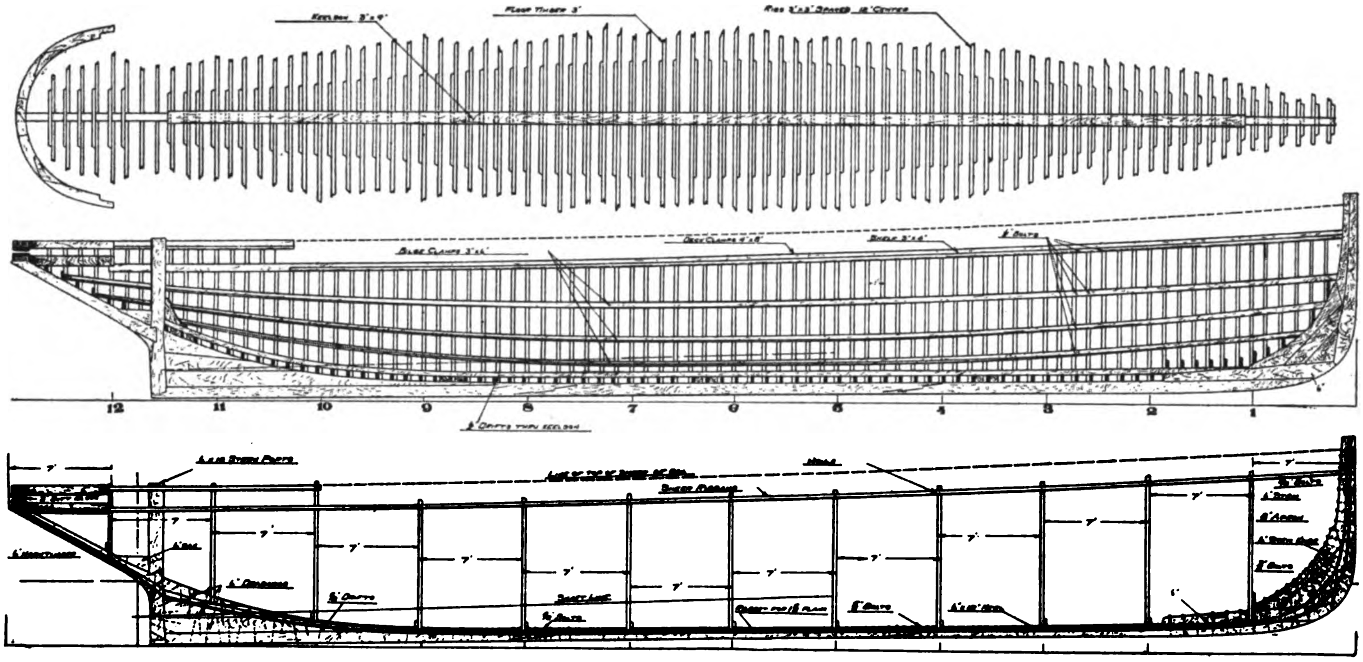


Fig. 2

1b. Description of Vessel

The design is for a small commercial power-driven vessel to be constructed of wood. Its principal over-all dimensions being:

Length over all, 91 feet.

Breadth, extreme, 17 feet 6 inches.

Depth, extreme, from keel to top of stem head, 13 feet 9 inches.

Therefore, the dimensions of mould loft floor required to lay vessel down are:

Length not under 100 feet (a few feet more than extreme over-all length).

Breadth not under 36 feet, if vessel's lines are to be laid down in locations similar to ones on lines drawing Fig. 1, with profile view and half-breadth water-line views separated, or 17 feet if lines are to be laid down with profile and half-breadth water-line views together, the profile being laid down first with one colored crayon, and half-breadth view with one of different color on same part of floor as profile view, the base line of profile being used as center line for water-line view.

As it is a more difficult matter to lay lines down in the second manner (both views together on one portion of floor), I will explain how work is done in that manner.

When "laying down" the lines of a vessel, the profile and half-breadth water-lines are laid down first and in such positions that inaccuracies of shape which cannot be seen on scale drawings can be corrected. An important duty of the mould loftsman is to correct inaccuracies and *fair* all the lines. The cross-sections are "laid down" *after* lines shown on profile and half-breadth water-line views have been faired or corrected, and it is usual to "lay down" cross-sections on a different portion of floor, or upon a large board that can be moved from the mould loft to bending room. The reason for doing this will be explained a little further along.

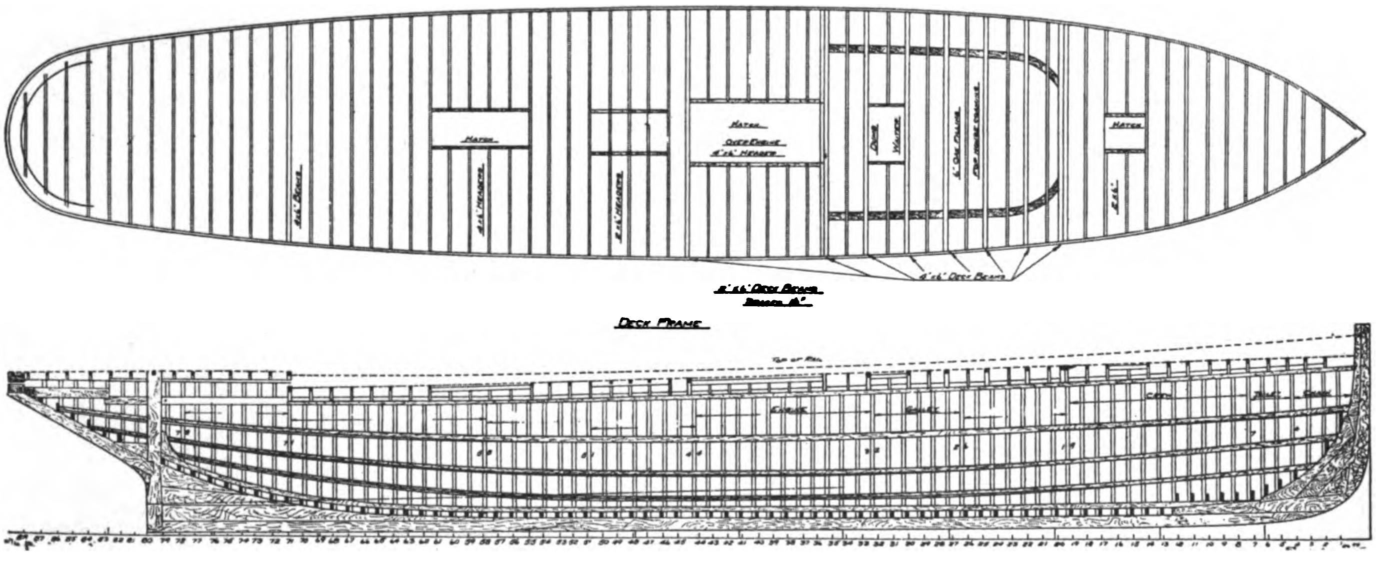


Fig. 3

1c. Fairing the Lines

It is a physical impossibility for a designer to get all lines shown on a scale drawing absolutely fair, and to take absolutely correct measurements from a scale drawing. Therefore, the mould loftsman first marks out the lines by using measurements supplied by designer and whenever a line laid down to these measures does not come absolutely fair and true he corrects it by moving any measurement point that is out of position. The mould loftsman must be careful not to materially change the shape of any line; *he only corrects inaccuracies.*

The art of fairing lines can only be acquired through practice, but in general it will be found that lines can be faired more easily if a certain definite plan of procedure is followed. I have found that it is best when laying down profile view to fair the sheer line first, the keel and stem outline next, and the rabbet next. When fairing half-breadth water-line it is best to fair deck outline first, the L.W.L. next, then water-lines below the L.W.L., beginning with one nearest to L.W.L., and last of all water-lines above water beginning with line next above the L.W.L.

The work of fairing lines really consists of two separate and distinct parts, the first or preliminary fairing being done just before each line is marked and consists of correcting apparent inaccuracies or irregularities that appear in the batten sprung to measurement points. The second fairing, done when buttock lines and diagonals are being marked in, is most important, because it is the final one made for the purpose of fairing the lines *in every direction.*

1d. Description of Mould Loft Floor

The floor of a mould loft must be perfectly level and smooth. It should be constructed of tongued and grooved strips of hard wood, and it is advantageous to have planks laid diagonal to side of floor that will be used as base line. Sometimes the floor of a mould loft is painted either a dull black or white, because colored lines show more distinctly on a painted surface.

Along lengthways edge of floor a fixed perfectly straight batten is secured, the inner edge of batten being used as a *base* line (1) when "laying down" and serving the double purpose of clearly indicating base line and also as a guide for ends of measuring battens when these are used for measuring "laying-down" lines. It is a good plan to paint base batten black and clearly mark along its top ordinate numbers and frame positions.

I will now assume that floor of mould loft with base batten is ready. (See Fig. 4.)

The first work is to mark on floor the over-all perpendiculars (2), space off ordinate or mould lines (3), and mark them across mould loft floor at exact right angles to base line.

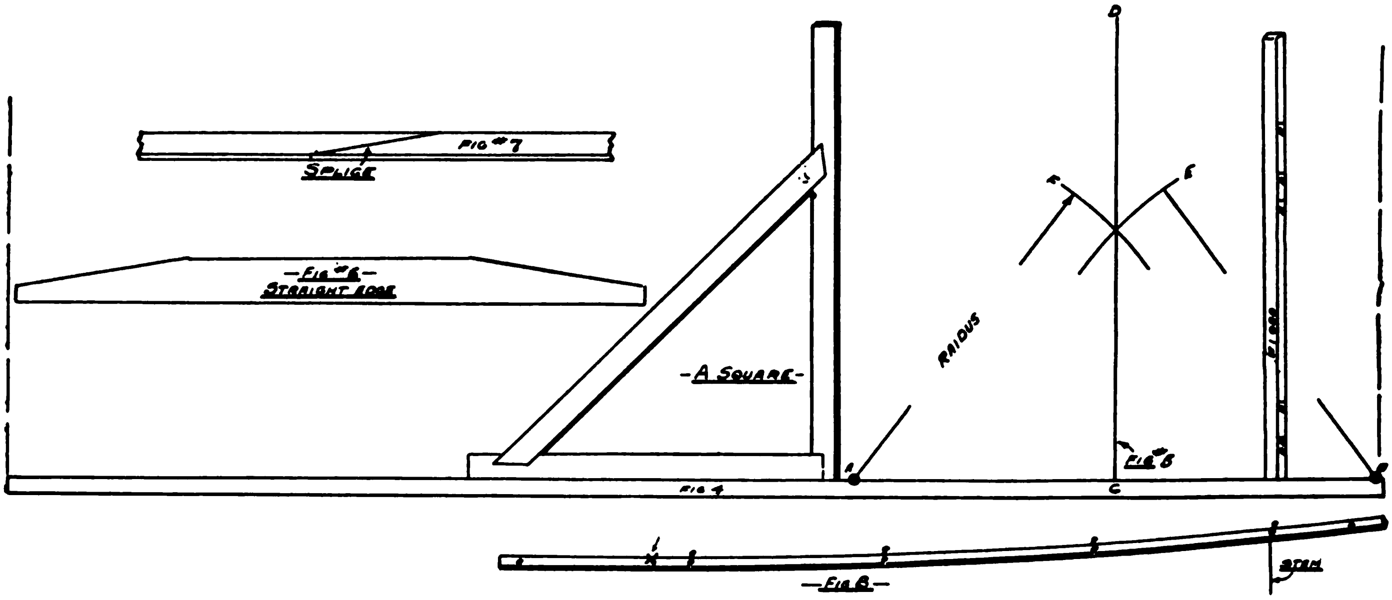
As "laying down" a vessel's lines really consists in making a full-sized reproduction of the designer's scale drawings, the mould loftsman must, before he begins his work, endeavor to clearly understand the designer's intentions as regards shape of lines.

Over-all perpendiculars (2) are marked off in this manner: A point is marked on base line to indicate where forward perpendicular is to be located and over-all measurement is taken from this point along base line. The after perpendicular is marked at point where over-all measurement reaches. These perpendicular lines must be at exact right angles to base and their length must be sufficient to enable fore and aft line of profile that is furthest from base to terminate against them. To insure that perpendiculars are at exact right angles, the mould loftsman first lays out the lines with a large A square and then proves their accuracy by checking in this manner:

1e. Explanation of Method of Proving That One Line is Drawn Square to Another

The line *A, B,* on Fig. 5, is a base line and it is desired to draw the long line *C, D,* perpendicular to it.

Place edge of one blade of A square to follow base line *A, B,* and draw the perpendicular line *C, D,* very faintly. To prove its accuracy use a pair of beam compasses, one point of which is placed at *B* and the other at *E.* Describe arc *E* and then measure from *C* towards *A* a distance equal to *C, B.* Describe arc *F* without changing compasses, and if it is found that point of intersection of the two arcs is exactly on perpendicular, the line *C, D* will be exactly perpendicular to *A, B.* If the intersection is not on line you will know that *C, D* is not exactly perpendicular.



1f. Description of A Squares Used in a Mould Loft

These are made of pine or mahogany battens about 1 to 1½ inches, glued together to form strips 4½ to 6 inches wide. The three pieces that form square are halved and glued together, great care being taken to get outer working edges of square exactly at right angles. A mould loftsman usually has one or more of these squares, the length of short blades being about two-thirds the length of long one.

On Fig. 5 an A square is shown.

When the two perpendiculars have been marked and proved, the mould loftsman proceeds to lay out ordinate lines (3), or lines that indicate positions of erecting frames. In this particular instance, the vessel being a wooden one, the ordinate lines 1 to 12 are also the lines that indicate where erecting frames, or first frames erected, are located.

Ordinate lines are laid out in this manner: The mould loftsman accurately measures along base line and makes a mark where each ordinate line (3) is located. He then places his A square at each point and marks the ordinate lines on mould loft floor, being careful to get them at exact right angles to base. The accuracy of ordinate lines can be proved by either proceeding in the manner explained by illustration Fig. 5, or by measuring from upper end of forward perpendicular parallel to base. *Note this:* If a line is drawn from forward to after perpendicular exactly parallel with base line and along this parallel line there is measured distances corresponding with ordinate point distances measured along base line, it is evident that if every perpendicular drawn from a point on base line cuts the corresponding point on upper parallel line, ordinate lines will stand at exact right angles to base.

After ordinate lines (3) are marked, the parallel water-line planes (4) shown on profile drawing are marked. These lines must be parallel with base line and the exact distance apart indicated on lines drawing. In this particular case, the lines are 12 inches apart. Water-plane lines, and in fact all long straight lines, are usually marked by means of a chalk line, and after their accuracy has been proved, they are re-marked more clearly with a crayon or pencil, using a long straight edge as a guide.

1g. To Mark the Long Straight Parallel Water-Lines on Profile by Using a Chalk Line

Measure up from base line, along forward and after perpendiculars, and mark points where each water-plane line (4) terminates. Next make similar measurements on two or three widely spaced ordinates and mark the points.

Now tightly stretch a well-chalked fine cotton line from a point on forward perpendicular to a corresponding point on after perpendicular and prove that the line is straight and parallel with base by observing that it exactly cuts points marked on widely spaced ordinate lines. When satisfied that line is correct, have one or more assistants stop the line at equal intervals by pressing it down to floor without shifting it, and then snap line section by section. If the snapping is properly done, the chalk on line will leave a perfectly straight mark on floor and you can accurately re-mark it in pencil or crayon by using a long straight edge as a guide.

1h. Description of Straight Edges Used in a Mould Loft

A mould loftsman must have one or more straight edges to help when marking straight lines of moderate length. These straight edges are generally made of several narrow strips of mahogany or pine glued together, the width of the strips being about 1 inch and total width of straight edge about 8 inches at center for a straight edge not over 16 feet in length. The ends are tapered as shown on Fig. 6.

When these lines have been marked, the profile view can be laid out. Measurements for doing this are obtained from table of offsets that is always attached to a lines drawing. The mould loftsman usually lays down profile view outline first, and in order to do this work accurately and in the quickest manner, he first transfers all measurements to a number of "taking-off" battens and then by using these "taking-off" battens in proper locations and butting one end of them against base line batten, height line measurements can be more quickly made than by using a rule.

1i. Description of "Taking-Off" Battens

"Taking-off" battens are straight pieces of pine having either flat or triangular cross-section and sufficiently long to enable the greatest height or width measurement to be transferred to them. One end of each batten is finished perfectly true and square, so that it can be butted against base-line batten and held there while a measurement is being transferred from "taking-off" batten to mould loft floor. On illustration Fig. 5 a "taking-off" batten with rectangular cross-section is shown, and on it I have marked a series of lines to indicate just how a mould loftsman marks measurements on such battens. The batten illustrated has marked on it all necessary height measurements for No. 1 ordinate. The lower mark indicates height bottom of keel is above base; the next mark indicates height of rabbet above base; the next mark indicates height of sheer above base; the next one height of center of deck line above base, and upper one height of top of rail. Thus, by placing this batten against base line at No. 1 ordinate position and having it follow ordinate line, the mould loftsman can quickly and accurately transfer measurement points for all profile height measurements on No. 1 ordinate.

All measurements for profile view are made from base line (1), and all measurements for half-breadth water-line view are made from center line (1a), in exactly the same manner that they are made by the architect when preparing the lines drawing.

The usual method of marking points of measurement on a mould loft floor is to mark a small dot or cross and enclose it within a circle, the center of dot or cross indicating the exact point of measurement and the point where pinning nail for guiding batten is driven. For this vessel the mould loftsman will require four battens for "taking-off" height measurements of profile view. This is because each batten has a rectangular cross-section, therefore, a separate series of measurements can be marked on each face. Thus, the first batten will have marked on it measurements for Nos. 1, 2, 3, and 4 ordinates, the second for Nos. 5, 6, 7 and 8 ordinates, the third for Nos. 9, 10, 11 and 12 ordinates, and the fourth heights for stem and stern.

I will now assume that all profile height measurements have been marked on battens and transferred to the mould loft floor. The mould loft floor will now have the appearance shown on Fig. 9, and the mould loftsman can proceed to mark in the profile outline. I will explain how this is done, but before doing it I will briefly describe the battens used in a mould loft for drawing long curved lines.

1k. Description of "Laying-Down" Battens Used in a Mould Loft

These battens are made of clear pine in long lengths, and if one length of material is not sufficiently long, two or more pieces are carefully spliced together, the usual method of splicing being a long tapered glued splice as shown on Fig. 7. By making a splice of this kind the batten will bend to a true curve. Three kinds of battens are used: (*a*) Battens that have the same cross-section area from end to end. These are used for guiding the pencil when drawing long lines that have a regular curvature from end to end, such as a sheer line. (*b*) Battens that taper towards one end. These are used for guiding the pencil when drawing lines having a curvature that changes at or near one end, such as the after end of a load water-line. (*c*) Battens that taper towards their center. These are used for guiding the pencil when drawing lines having an abrupt change of curvature some distance from end, such as the forefoot of a stem. In a mould loft there is always a large number of battens of each kind, the dimensions of cross-section varying. Some of the battens have a square cross-section varying in size from $1\frac{1}{2}$ by $1\frac{1}{2}$ inch down to $\frac{3}{4}$ by $\frac{3}{4}$ inch. Another kind of batten used very frequently is one having its width greater than its thickness. It is usual to make these battens two times as wide as they are thick, some being 2 inches wide and $\frac{7}{8}$ inch thick and others various sizes down to $\frac{5}{8}$ inch wide by $\frac{1}{8}$ inch or less thick. The very small battens are used for guiding the pencil when drawing very abrupt curves.

1l. Explaining the Way to Use Battens for Guiding the Pencil When Drawing Long Curved Sheer and Other Lines on a Mould Loft Floor

For the sheer and top of rail lines (5) the mould loftsman selects a rectangular cross-section batten that is sufficiently stiff to require a little pressure to bend it to the measurement points. This batten should, if possible, be sufficiently long to extend from end to end of line, but if this length of batten is not available a shorter one can be used; but it is important to remember great care has to be taken, when using a shorter batten, to prevent a flat spot appearing in line at points where end of batten reaches to. The mould loftsman drives a wire finishing nail, a little longer than width of batten, through the center of each sheer measurement point, and when this has been done he bends batten against the nail and holds it in place by driving additional nails against the other edge of batten. Frequently with the batten resting against all measurement point nails there is some slight irregularity in the curve. Irregularities must be corrected, by the mould loftsman, without making any radical change in line, so as soon as sheer batten is bent, the mould loftsman looks along it, notes any irregular spots and has his assistant move nails here and there until the line is fair and batten is moved *as small a distance as possible* (average) from the original measurement points.

It is very important to remember that whenever a long batten is bent to a curved line the tendency is for ends of batten to assume a flat shape. The mould loftsman, knowing this, always lets the ends of a batten extend several feet beyond the termination points of a curved line and he puts sufficient tension on the extended portions to obliterate any flatness. This same method is followed when using a batten that is not sufficiently long to reach from end to end of a line. The last several feet of such a batten is not used as a guide for marking, but as an end for the purpose of eliminating flatness of curve. Fig. 8 shows a short batten in position for marking a portion of sheer line of design being laid down. Note the extension of batten ahead of stem, also note *X* mark, which indicates where marking of line must terminate until batten is moved to a position that will enable the line to be continued aft in a fair curve. I have shown a short batten in use because I desire to call your attention to the importance of allowing the ends of such a batten to extend.

The whole of sheer line (5) is marked and then nails are driven at points along outside of keel line (6), batten is bent, fastened in place, faired if necessary, and outside of keel line (6) is marked. It is usual to commence to mark this line from stern and work forward, a fairly stiff batten being used for portion of line that extends from stern-post to No. 2 ordinate, and then a center tapered batten that is sufficiently limber to bend around the forefoot up to stem head. Small battens are used for bending around curves of stern-post and horn-timber. After profile outline is marked, nails are driven along rabbet (7) line points and rabbet line is marked very faintly. This line is marked faintly because a little later it may be found necessary to change its shape at various points, especially along forefoot. I will explain later the reason why this change may be found necessary.

The center of deck line (8) is next "laid down".

After profile outline and rabbet are marked the mould loftsman lays down the half-breadth deck and water-line view. Measurement points for this view are obtained from offset tables and are marked on taking off battens in exactly the same manner that measurements for sheer were marked. You will remember I mentioned that it is my intention to explain the way to lay down half-breadth water-lines on same space that profile is laid down, therefore, base line for profile now becomes middle line for half-breadth water-line view and ordinate lines used for profile become ordinate lines for half-breadth view.

To avoid possibility of confusing the points and lines of profile with those of half-breadth water-lines I use a different colored crayon for each set of lines. My usual practice, on a white painted floor, is to use Dixon's black crayon for perpendiculars, ordinate lines, parallel straight water-lines on profile, sheer and profile outline, rabbet and bearding line.

Blue crayon for deck outline and water-line of half-breadth water-line view.

Red crayon for buttock lines on both profile and half-breadth view.

Green crayon for diagonal lines.

Thus each set of lines stands out clear and distinct, and it is an easy matter to follow any selected line.

When all half-breadth measurement points are transferred to mould loft floor the mould loftsman marks the lines that indicate half-width of rabbet (9) at stem, keel and deadwood, on half-breadth water-line view. This line extends from forward to after perpendiculars and is drawn the distance out from center line of keel that rabbet is away from center line. This is usually half siding of keel, stem and deadwood. In this design the line is parallel to center line of keel, but frequently in small vessels the width of rabbet increases at shaft-log. Measurements for rabbet widths at each ordinate are obtained from offset table. He next marks lines at stem and stern, to indicate half-widths of each water-line at its points of termination (10).

If you look at bow of any vessel you will see that the extreme forward end of stem does not taper down to a knife edge but has some width. On the design being laid down this width is 1 inch at stem head, therefore, the half-width of deck at extreme forward end of stem is ½ inch, and this ½ inch width is carried down to where water-line No. 3 cuts stem, and from this point it begins to increase in width until at a point about 1 foot aft of No. 1 ordinate it becomes the same as that of keel.

The width of front of stem is shown on half-breadth water-line view by a line drawn the proper distances out from center line of keel (10). On Fig. 1 illustration this (10) and the rabbet line (9) are clearly shown.

The mould loftsman transfers termination points of water-lines and rabbet in this manner (bear in mind that base line is now also center line of half-breadth view): spot in line between Nos. 1 and 2 ordinates. This irregularity can be removed by either moving batten out at No. 1 ordinate and letting it remain in its place at No. 2, or by moving batten in at No. 2 ordinate and letting it remain in its place at No. 1. The question for mould loftsman to decide is which of the two methods of correcting the irregularity is best. The irregularity may only be a small one, but it is very important to correct it in such a manner that the designer's intention as regards shape of lines be adhered to. Bear in mind that in the majority of instances an alteration in the shape of one water-plane will affect one or more of the water-planes immediately above and below the one that is changed, and thus the designer's ideas of form can be changed very materially by a mould loftsman unless he is very careful. Fairing a line should always be done in such a manner that shape remains as nearly like the drawing as it is possible to have it.

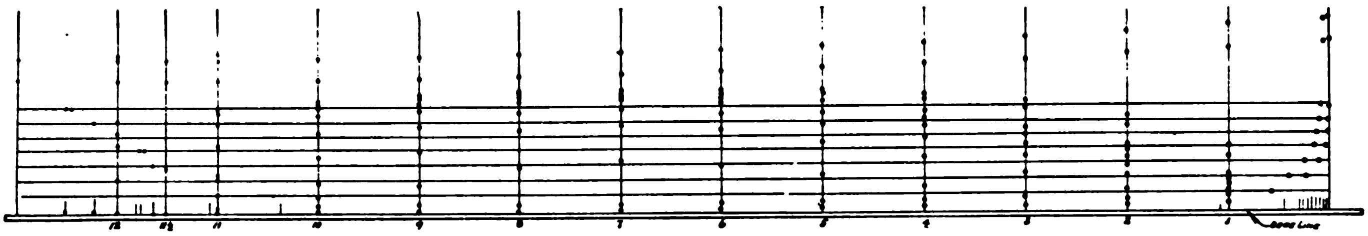


Fig. 9

He uses a square, placing one edge against base batten and other edge to cut point where one of the parallel water-plane lines crosses stem or stern outline of profile, or rabbet, as the case may be; the standing edge of square is then used as a guide and a line drawn from point on profile down to line that indicates half-width of front of stem, or of stern, or of rabbet, as the case may be. This line is drawn faintly because it is not a portion of laying-down lines.

Fig. 9 illustrates appearance of mould loft floor when profile and half-breadth view measurement marks have been transferred, and Fig. 10 illustrates appearance when lines 1 to 19 have been marked on floor ready for fairing.

The mould loftsman when laying lines down to measurement points such as these are makes the longitudinal lines fair to the eye by correcting irregularities due to evident mistakes in measuring offsets from scale

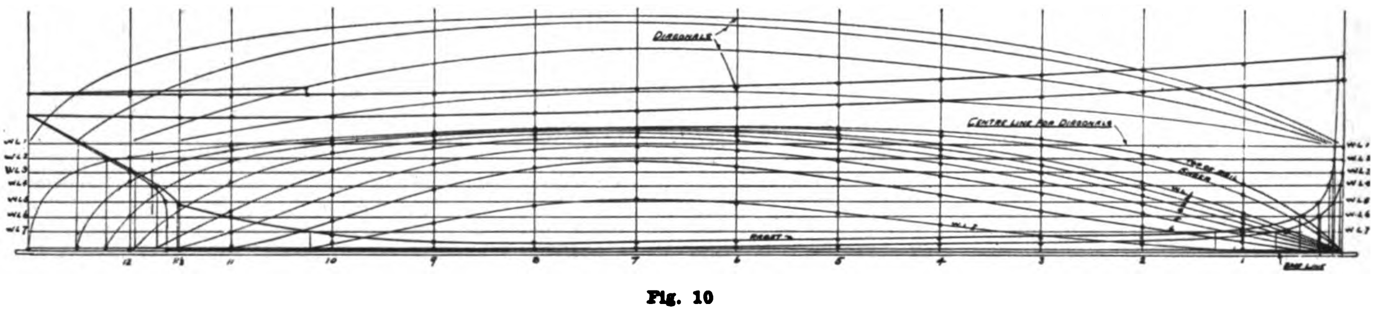


Fig. 10

Forward and after points of termination of all water-lines are drawn and transferred in this manner and after this has been done points where each water-plane line crosses rabbet line are transferred down to half-width of keel line (rabbet).

After the points of termination water-planes and of rabbet have been transferred, the top of rail outline (11), deck outline (12), L.W.L. (13), and half-breadth water-planes (14 to 19), are marked, the various lines being laid down in the order indicated by numerals. The preliminary fairing of these lines is an important detail.

I will assume that top of rail (11) and deck outline (12) have been laid down and found to be accurate. The next line to lay down is the L.W.L. (13). Now let us assume that when batten is bent to measurement points of L.W.L. it is found that there is an irregular drawing, leaving the final fairing of lines until body plan has been laid down and buttocks and diagonals drawn. *Accurate fairing cannot be done without the use of buttock and diagonal lines.*

III. Laying Down Body Plan

The body plan is next laid down on a portion of floor entirely apart from longitudinal profile and half-breadth water-lines. The floor is prepared by marking base, center line and parallel water-plane lines, and then measurements for cross-sections are taken, on measurement battens, *from the profile and half-breadth lines already laid down* and transferred, because by doing the work in this manner cross-sections will be laid down to corrected measurements of lines already laid down and not to original measurements given on table of offsets. You must bear in mind that when laying down lines it is necessary to have corresponding measurements alike on all views, therefore, whenever a line is changed on one view, a similar change must be made on all other views of same line.

Fig. 11 shows appearance of floor after straight parallel water-plane lines, center line and base line for cross-sections have been laid down, and Fig. 12 its appearance after cross-section outlines have been marked.

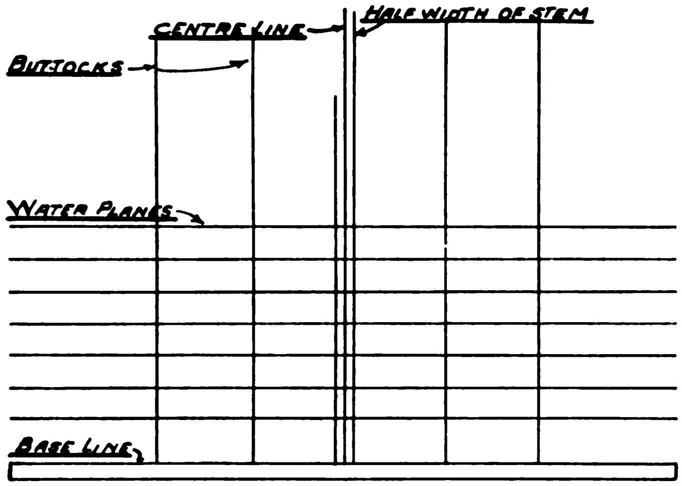


Fig. 11

The cross-section outlines are at this time marked on floor very faintly, because later it will no doubt be found necessary to make corrections, and in addition to this it will be necessary to take off the thickness of planking after cross-section shapes are faired.

11. Taking Off the Thickness of Planking

The lines of this vessel are drawn to *outside* of planking, and as it is necessary to use patterns of cross-section shapes as guides for shaping frames, the mould loftsman, after lines have been faired, takes off the planking by marking lines the exact thickness of plank inside cross-section shape lines. This is done by setting a pair of carpenter's compasses to exact thickness of planking, bending a batten to follow outline of the section and then by letting one leg of compasses follow along inside edge of batten, the other leg, with pencil point attached, will scribe a new line the thickness of plank inside cross-section outline.

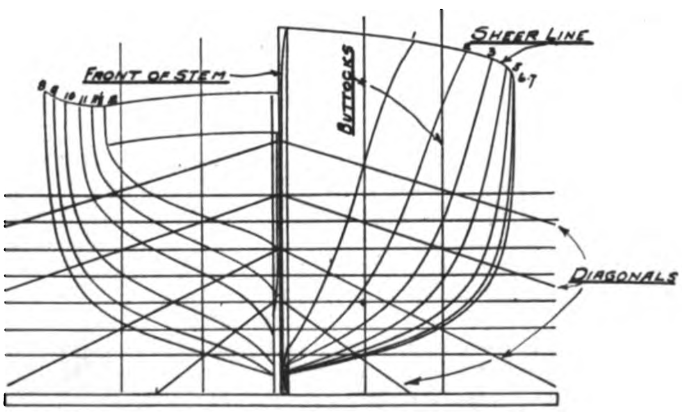


Fig. 12

On Fig. 13 I show an enlarged view of two cross-section outlines after thickness of planking has been taken off. To aid you in understanding the drawing I have shown original outlines in broken lines and outlines after thickness of plank has been taken off, in full. This illustration will be described after I have explained how lines are faired.

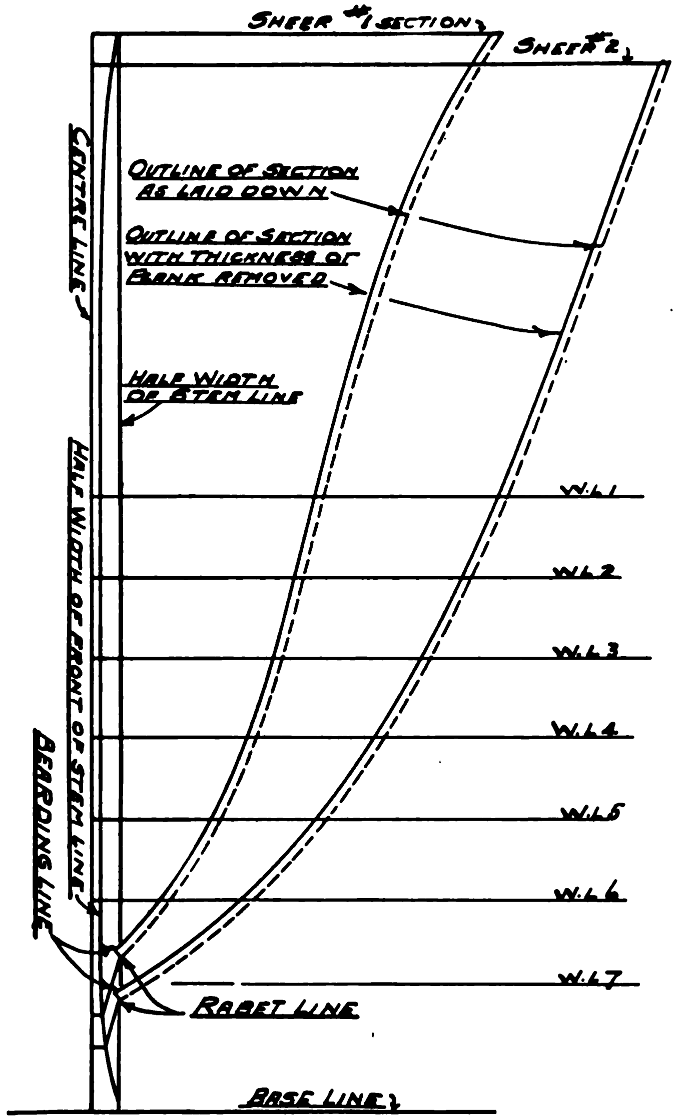


Fig. 13

10. Fairing the Lines

I will assume that all profile longitudinal lines, half-breadth water-lines and cross-section shape lines have been laid down, and that measurements on all views correspond. To fair these lines it is necessary to make use of buttock and diagonal lines, because fore-and-aft and transverse lines may look fair when viewed as they must be on a mould loft floor as plane surfaces taken at right angles to each other, but when viewed from other angles irregularities may be apparent. Therefore to fair the lines, which really means proving they are fair, buttock straight lines are marked on both cross-section and half-breadth water-line views, and then by making measurements on cross-section view and transferring them to proper places on longitudinal profile view, points are obtained for the curved buttock lines on profile. Some additional points for getting buttock lines shaped at ends of profile are obtained by marking verticals from points on half-breadth water-line view to corresponding water plane on profile. Fig. 14 shows an enlarged view of forward portion of longitudinal profile and water lines, with buttock transfer lines and buttock shapes marked. For the purpose of making the illustration clearer, I have marked half-breadth water-lines in broken lines and buttock outlines and transfer lines in full.

It may be found that when a batten is bent to points marked for buttock curved lines some points will be out. When this occurs it is necessary to look over longitudinal and cross-section lines very carefully and determine change necessary to make buttock line fair. One of the best ways to fair is to let buttock line batten bend to a fair curve, paying no attention to the point, or points, that is out, and then measure from batten to where buttock does not cut its measurement point, transferring this measure to corresponding buttock line on cross-section plan, and ascertain if a fair curve of cross-section can be obtained when cross-section shape is altered to cut the new point. If it can be obtained, transfer corrected cross-section measure to half-breadth water-line view and note if, when water-line is changed to meet this point, the water-line shape will be fair. If it is fair to look at, you can be reasonably certain that the change should be made. In practice it will be found necessary to make several changes before all lines are fair and measurements on all views correspond. Take one buttock at a time, beginning with buttock nearest keel.

After buttocks have been marked and corrected, the final fairing is done by means of diagonals.

1p. Final Fairing by Using Diagonals

Straight diagonal lines (38 on cross-section view) are marked, measurements are taken along them and transferred to mould loft floor immediately above longitudinal profile view, the upper water plane of profile view being used as center line for diagonals. Bear in mind diagonal measurements are taken from center line of cross-section view along diagonal straight lines to where each cross-section outline crosses a diagonal. Measurement battens are used.

On Fig. 10 I have drawn the diagonal curved lines and indicated the line on profile view used as center line when laying down these lines.

Diagonal curved lines indicate the approximate path of travel of water around and under a vessel, and if lines of vessel are fair, the diagonal curved lines will be fair curves from end to end. Any irregularity in one of these lines will indicate a flat spot or a bulge in form, and of course it is necessary that mould loftsman correct diagonal, cross-sections and half-breadth water-line at any point where diagonal shows any irregularity.

The fore-and-aft, and cross-section lines have now been laid down and faired, but before making the templates, it is necessary that shaft line be marked, that correctness of rabbet be proved, and that bearding line be marked at its proper distance from rabbet of keel, stem, deadwood and stern.

To mark shaft line use measurements given on table of offsets, mark points where forward and after ends of shaft line terminate, stretch a chalk line from point to point, and then prove that line is correctly located by making an intermediate measurement along an ordinate the line crosses and checking it with measure for that ordinate given on table of offsets.

The important thing to bear in mind when laying out shaft line is to have line at engine location sufficiently above top of keel to allow engine to be installed without having to cut away any construction material, and to have line at propeller wheel location sufficiently below water to insure that propeller will be properly immersed and clear hull.

As this vessel is to have twin screws, the shaft line passes through hull at some distance out from center line; this does not alter method of laying down shaft center line, but it makes it necessary to mark lines on both profile and half-breadth water-line views.

1q. Rabbet and Bearding Line

The rabbet indicates line where outside of planking butts against keel, stem, etc., and bearding line indicates

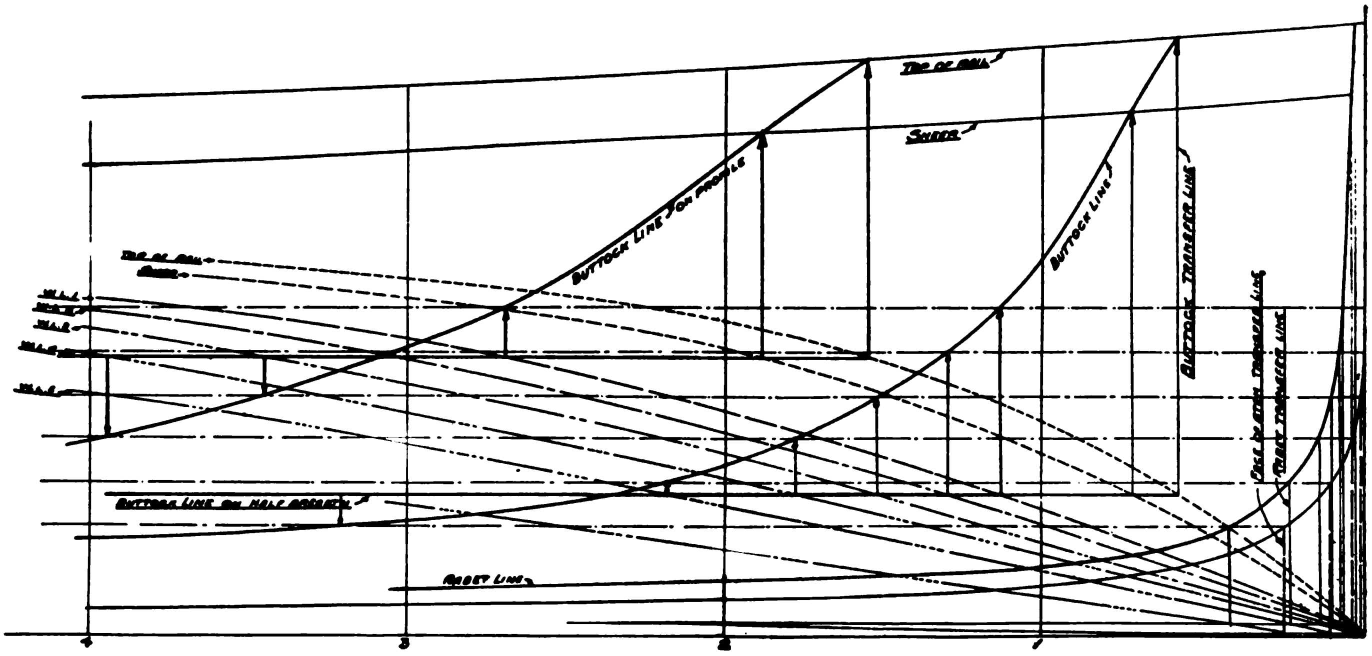


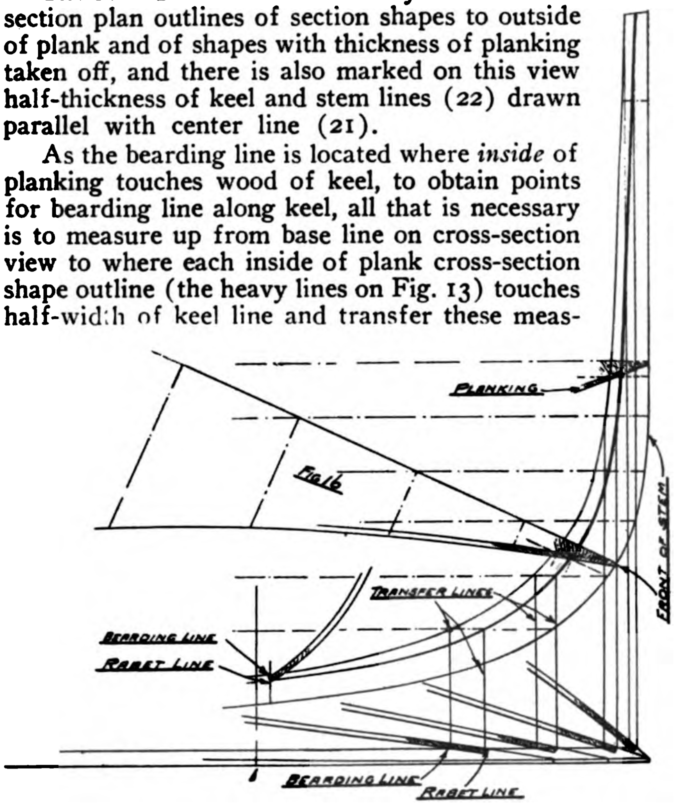
Fig. 14

where inside surface of planking touches wood of keel, stem, etc., therefore, the two lines *must* always be at least the thickness of planking apart at points where frames are "dead flat", and must, of course, move further apart as inclination of bottom of frames becomes more vertical. To find the measurement points for bearding line proceed in this manner:

11. Obtaining Measurement Points for Bearding Line

The mould loftsman has already marked on the cross-section plan outlines of section shapes to outside of plank and of shapes with thickness of planking taken off, and there is also marked on this view half-thickness of keel and stem lines (22) drawn parallel with center line (21).

As the bearding line is located where *inside* of planking touches wood of keel, to obtain points for bearding line along keel, all that is necessary is to measure up from base line on cross-section view to where each inside of plank cross-section shape outline (the heavy lines on Fig. 13) touches half-width of keel line and transfer these meas-



Figs. 15 and 16

ures to proper ordinate on profile view. A batten bent to cut these measurement points will, if rabbet line is fair, bend to a fair curve and indicate the exact shape and position of bearding line along keel. Measurement points taken from cross-section shapes will only enable bearding line to be drawn from No. 1 section aft to No. 12, therefore, it is necessary to obtain additional measurement points for marking bearding line along stem and stern. These points are obtained in the manner indicated by Fig. 15 illustration.

Fig. 15 is an illustration of stem and on it is shown rabbet and bearding lines and cross-section shape of stem at various points. There is also shown lines to indicate method of transferring points for obtaining shape of rabbet and bearding lines on profile view. The bearding line indicates where inside of plank touches wood of stem, keel, etc., therefore, if a line to indicate thickness of planking is drawn inside of and parallel with each water-line where it crosses the half-width of stem line, points for bearding line are obtained, and by measuring distance each point is away from rabbet line and transferring measurements to water-line planes on profile points for position of bearding line at each water plane can be obtained. The easiest method of transferring both rabbet and bearding line points to the profile view is by drawing verticals in the manner shown on Fig. 15.

On the Fig. 15 illustration some of the water planes have been omitted from the half-breadth water-line view. This has been done to avoid confusing you by having too many lines.

When points are marked on profile a batten can be bent to cut them and shape of bearding line from No. 1 section position to stem head marked. This mark should be drawn faintly at first, because it will no doubt have to be corrected along the portion where outline of stem is not at right angles to water plane.

If you look at Fig. 15, you will note that outline of stem near where three lowest water planes are drawn does not lie at right angles to the water planes. It therefore is necessary to prove the accuracy of bearding and rabbet lines at these points. This is done by drawing diagonal lines on profile at right angles to stem contour, measuring widths and marking outline shape of diagonal.

On Fig. 16 I show one of these diagonal lines and have marked at its forward end the thickness of plank line and cross-section of stem.

It will generally be found that at points where contour of stem stands at an angle that is much greater or less than a right angle (like at two water-lines on illustration) some correction to both rabbet and bearding lines will have to be made.

The cardinal principle of laying down lines of this kind is to first mark shapes by using measurements given on offset or transferred from other views and then correct as required.

You will note by referring to Figs. 1 and 2 that rabbet line runs in a fair sweep aft to stern-post and then, after the slight jog at stern-post is past, it again runs in a fair line aft to stern. The rabbet line can, therefore, be accurately marked when laying down the longitudinal and body plan lines, and bearding line can be marked from measurement points obtained from body plan after planking is taken off. As there is no shaft log, the after deadwood, outside of rabbet, is practically one thickness from rabbet to keel and stern-post. The fairing of stern is done by running in two or three additional short buttock lines (beginning about No. 10 ordinate position) and outlining one or two additional cross-sections between No. 12 ordinate and stern. By transferring measurements taken along these additional buttocks and cross-sections points for fairing stern can be obtained and the accuracy of stern outline proved.

It is necessary to mark rabbet and bearding line along fashion pieces of stern (the curved pieces of timber that form the stern). The way this is done is described below.

The sheer line (5) and top of rail line indicate location of upper and lower bounding lines of fashion pieces of stern, and the space between these lines indicates width of planking that continues around curved face of fashion piece. This being the case the thickness of plank around outside of fashion piece is "taken off" by drawing a line the exact thickness of plank inside line that indicates outside shape of fashion piece of stern. This line will touch bearding line of horntimber at its after termination point and will indicate bearding line around fashion piece. The outside of plank line around fashion piece is the rabbet line.

A sufficient number of lines have now been laid down and faired to permit the mould loftsman to lay out construction details.

15. Laying Down Construction Details

Builders have learnt that the easiest and least costly method of getting shapes of the numerous pieces of material that compose a hull is to make wood templates, or patterns, of each piece and use them as guides for marking and shaping the pieces of material that will be used for constructing the hull.

Making templates is comparatively easy, and providing the lines have been properly faired and template maker does his work properly, the templates will enable the shipbuilders to accurately shape the pieces at far less cost of labor than if they worked directly from measurements taken from the lines marked on mould loft floor. It has been estimated that every cent expended for mould loft work saves *fifty* cents of labor.

Templates made by mould loftsmen are usually made of wood. For templates of a small craft, like this one, basswood is an excellent material because it is light in weight, tough, and not easily split by nails or tacks. For small templates that will be used as patterns material about ⅛ or 3/16-inch thick is correct. Moulds that will be used as guides when setting up steam-bent frames must be made of heavy material (from 1 to 2 inches thick) because they must have strength enough to withstand strains caused by ribs bearing against the longitudinal ribbands that are fastened to mould templates of this kind.

In this craft transverse framing below deck is composed of steam-bent ribs to which sawed floor timbers are attached, and therefore mould templates of heavy material must be made.

I will, before proceeding further, explain the two usual methods (steam-bent and sawed) of constructing transverse framing of small craft and ships.

1t. Steam-Bent Framing Described

The transverse framing of boats and small commercial or pleasure craft is usually steam-bent to shape. After keel, stem, stern, etc., are set up a certain number of temporary frames (called moulds), made of rough lumber and shaped exactly like body plan outlines laid out on mould loft floor, are set up at indicated points (the points 1 to 12 shown on Fig. 1 are points for erecting temporary moulds), and then a number of longitudinal ribbands are run outside these moulds and securely fastened to them, to stern and stem rabbet, and to deadwood. These ribbands are made of rather heavy material because they have to withstand the outward strain of frames until they are properly secured.

When these ribbands are fastened to the moulds their inside faces accurately follow the shape that outside of frame of vessel must be because the moulds to which they are fastened are sufficiently close to properly guide the ribbands, and the outside edge of moulds is exactly like the shapes laid down on mould loft floor. Of course the ribbands must run in fair, unbroken sweeps from bow to stern. Lower view on Fig. 2 shows moulds in position with sheer ribbands in place. In a craft of this size about fifteen ribbands will be run in the space between sheer and keel.

To frame a boat, or vessel with steam-bent ribs the builder softens each rib with steam, and while hot bends it to shape over a properly shaped form. When a rib is cold and set to its shape it is removed from the form, beveled, fitted in its place, and secured temporarily, by driving nails through the ribbands into rib. You can readily understand that when a rib touches all ribbands it crosses the builder knows that it is shaped correctly. Several ribs are located between each two moulds.

The limit of size of rib that can be bent without the use of special bending apparatus is about 3 by 4 inches sided and moulded dimensions.

The bottom ends of ribs of this kind are secured to keel, and each pair of ribs is tied together by riveting, or bolting, a sawed floor timber to them.

When a boat or vessel, is framed in this manner it is only necessary for the mould loftsman to lay out shape of boat at each mould position; to do more than this would be a waste of effort. The templates, or patterns, of floor timbers can readily be made, after ribbands are in place, by the builders marking location of each floor on keel and then cutting out thin templates to fit in each floor position.

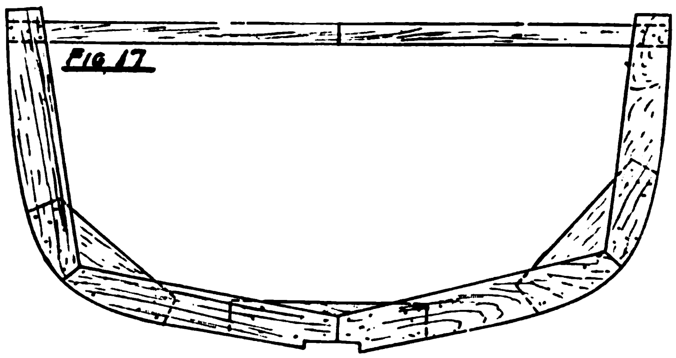
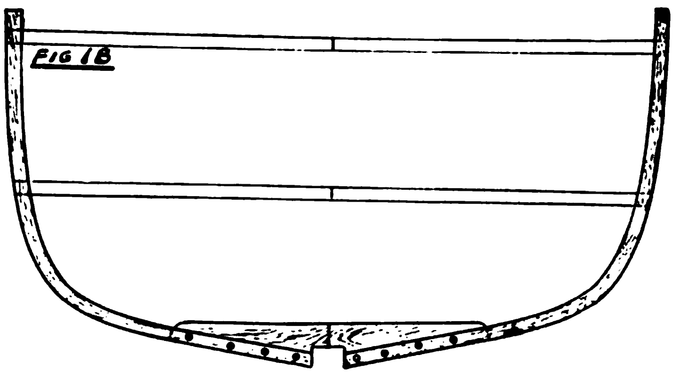


Fig. 17 shows a mould template put together and ready to fit in position, and Fig. 18 shows a pair of steam-bent ribs fastened together with a floor timber.

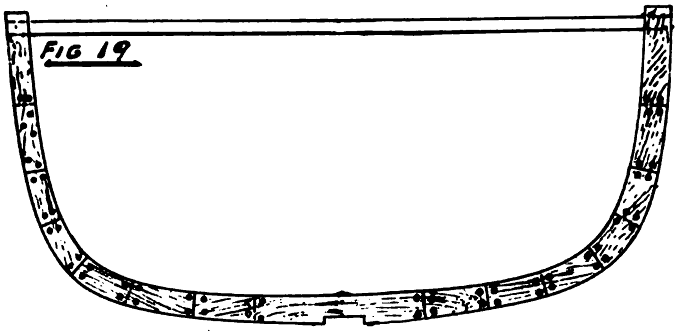


1u. Sawed to Shape Framing of Vessels

The transverse framing of vessels having frames made of material that is too heavy to steam bend is sawed to shape, each frame being composed of several pieces of material fastened together with bolts or rivets.

As frames of this kind have to be cut out of straight grained material the curvature of frame must be considered and the several pieces that compose a frame must be cut and secured in such a manner that short grain, which cannot be entirely avoided at ends of each piece, will not weaken the frame when it is assembled. To achieve this end it is usual to make each frame double (of two sets of pieces fastened side by side) and place the short grain portion of one piece alongside the long grain of an adjacent one. Thus when the several pieces are fastened together the frame is of equal strength from end to end.

Fig. 19 shows a pair of sawed frames assembled and ready to erect in position.



When a vessel has a frame of this kind the mould loftsman must lay out every frame and bevel, and make templates of the pieces, because each piece of frame must be sawed to exact shape, then beveled and assembled so accurately that when a frame is set up its outer shape will be exactly in accordance with plan.

IV. Marking Construction Details of Keel, etc., on Mould Loft Floor

Before the mould loftsman can make templates of the pieces that compose stem, keel, etc., he must mark on mould loft floor the longitudinal construction details of each piece of material, and on each piece there must be marked rabbet and bearding line, and any cross-section diagrams necessary for the builder.

I have explained how lines are laid down and faired, and Fig. 10 illustrates the appearance of mould loft floor with all longitudinal lines, except bearding line, marked. The bearding line points are obtained from corrected body plan transferred to proper locations on keel and line is marked in manner previously explained. The mould loftsman can now proceed to outline the longitudinal keel, stem and stern construction details. These are usually laid out in accordance with measurements taken from scale drawing of construction, but the mould loftsman had to make any corrections that fairing of lines has made necessary.

The construction details are laid out on same part of mould loft floor that lines are laid down on, the base line, bottom of keel line, rabbet and bearding lines already laid out being used for construction details. The likelihood of confusion arising by doing this is eliminated if a different color crayon is used for construction details.

When laying out construction details the mould loftsman should first mark measurement points for inside of stem, inside of keel, and inside of stern and deadwood and when these lines have been drawn he should mark scarphs and lay out fastenings.

Points to remember when laying out construction details are:

(a) There must be a sufficient amount of good solid wood back of stem and stem-knee rabbet to securely hold all fastenings of planking.

(b) There must be sufficient material above every scarph of stem and keel to hold the fastenings securely.

(c) The scarphs and joints must be laid out in such a manner and in such positions that short-grained wood is eliminated or supported by adjoining long-grained wood.

(d) The various pieces that compose keel, etc., must be laid out in such a manner that they can be got out of available widths and lengths of material.

(e) The fastenings must be driven and located in such a manner that they will tend to draw the pieces together, as the material shrinks and swells, rather than force them apart.

(f) The scarphs and joints must be laid out in such a manner that they will have at least the required strength. This means that scarphs must be of ample length, must be hooked if possible, and there must be a proper number of fastenings through them.

On illustration Fig. 2 every detail of keel construction is shown, but I think it will possibly avoid confusion if I explain the construction details.

The keel is composed of one stick having a scarph near its middle length. The scarph is hooked and has eight ⅝-inch bolts and four driven fastenings. A piece of forward deadwood fastens on top of forward end of keel, and three-piece stem knee being fastened to this deadwood and to keel. The stem fastens to stem knee and butts against forward end of keel. Apron above stem knee is formed of a separate piece of material, the line of joint with stem following along bearding line. Fastenings are clearly shown on drawing. Aft the deadwood is formed of two pieces of material that rest on top of keel and butt against stern-post. Stern-post is tenoned into after end of keel, and horntimber is dovetailed into stern-post and supported by outside knee and inside deadwood. The after end of horntimber, as you will note, is cut to receive the lower of the two fashion pieces, the lower edge of which must follow line that lower edge of top strake of plank follows and be beveled to receive planking ends of planks that will terminate along this fashion piece.

The upper fashion piece is placed sufficiently above the lower piece to enable its upper edge to follow line of sheer and the top of this piece must be beveled to crown that deck will have. No rabbet need be cut in either of the fashion pieces, because the planking continues around stern and the lower edge of strake that goes around the lower fashion piece is beveled to form a mitre or blind joint. In sterns of this kind all planks below the fashion piece will either terminate against the lower edge of fashion piece planking and fasten to fashion piece, or terminate against horntimber or deadwood and fasten in rabbet of these pieces. Every fastening and joint should be marked on mould loft floor, and in addition to this it is well to mark on each separate piece the dimensions of material (thickness) and diameter of fastening.

When the principal construction details have been laid out the templates can be made.

IW. Making Templates of Keel, and Other Construction Details

This is done by a simple method of transferring outlines and principal marks directly to template material in the manner explained below and illustrated by Fig. 20, which is an enlarged view of stem, as laid down on mould loft floor, with tacks in position for transferring shape of apron to template material.

IX. Describing Illustration Fig. 20

Fig. 20 shows outline of a portion of stem. It is necessary that templates be shaped exactly like the mould loft drawings and that there be marked on them an exact reproduction of rabbet and bearding lines, of scarphs, and that all fastenings be shown in accurate positions.

To redraw the lines would entail endless labor, so the

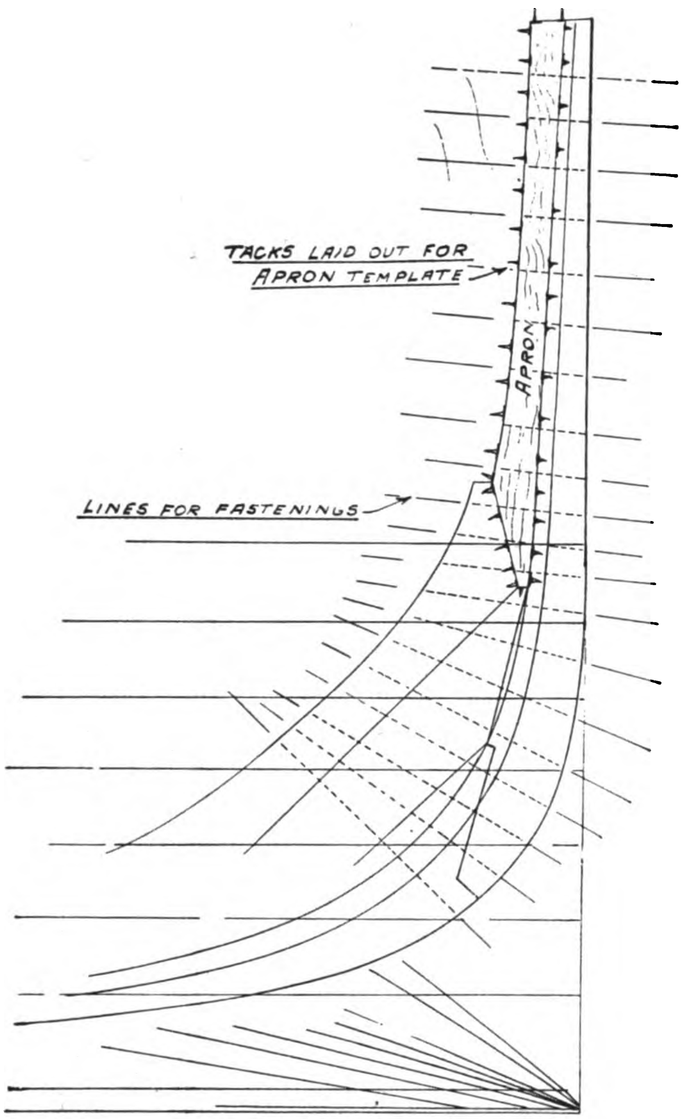


Fig. 20

mould loftsman lays along the lines he desires to reproduce a number of tacks, the head of each tack being placed exactly on line. On Fig. 20 I show tacks in place.

Fastenings are transferred by extending the center line of each fastening a sufficient distant outside and inside where template material will cover to enable line to be used as a guide for a straight edge.

When tacks are placed the template material is carefully laid on top of them and the mould loftsman then forces the soft wood template down on the sharp heads of tacks by either hitting it with a mallet or stepping on it.

The force used must be sufficient to cause the tacks to adhere to template material.

The template material is carefully lifted and turned, and you can readily understand that if a light batten is bent to follow against heads of tacks that have adhered to tempate material, an accurate reproduction of all lines can be marked, and then if the template is cut along its outline it will accurately represent the shape of piece with rabbet and bearding lines properly marked.

To complete a template, mark on it this information:
(a) Thickness of material.
(b) Diameter of fastening.
(c) Size of rabbet (thickness of plank).
(d) Name of template or its recording numeral.
(e) And if by reason of construction details or shape it is necessary to mark a cross-section view, this is done.

On stem templates cross-section views are necessary, because the width of front of stem is not indicated on template.

In this manner a template for each separate piece of material is marked out and when all have been completed they are laid out on mould loft floor and proved by fitting them in place over construction lay-out plan.

A keel template is seldom made when keel is straight and its construction such that outline, rabbet, and bearding line, can be quickly transferred directly to keel material. In such cases the frame or mould positions are laid out on a long rod or staff, transferred to keel material, and then points for laying out keel with its rabbet are obtained by taking measurements from mould loft floor.

The laying down problem I have explained is a very simple one because it has not been necessary to lay out any sections taken at obtuse or acute angles, or to cover curved or irregular surfaces. As I will next explain a laying down problem that will call for laying out acute angle sections and shape of surface covering, I think it will prove advantageous to explain a few simple problems, because the problem of accurately laying out sections that cut a figure on a line that is not at right angles to a named line is difficult if the mould loftsman does not have some knowledge of the fundamental rules for laying out sections of solids. (See Chapter IV.)

Iy. Laying Out a Deck Beam When the Crown and Length is Known

The round in a deck beam is usually a segment of a circle of large radius and, therefore, when the crown, or versed sine (the distance B D on Fig. 21), and length of chord (distance A C on Fig. 21), is known any beam can be laid out by using one of the methods explained below.

Having the chord and versed sine of the segment of a circle of large radius given, to find any number of points in the curve by means of intersecting lines.

Let A C be the chord and D B the versed sine.

Through B (Fig. 21) draw E F indefinitely and parallel to A C: join A B, and draw A E at right angles to A B. Draw also A G at right angles to A C, divide A D and E B into the same number of equal parts, and number the divisions from A and E respectively, and join the corresponding numbers by the lines 1 1, 2 2, 3 3. Divide also

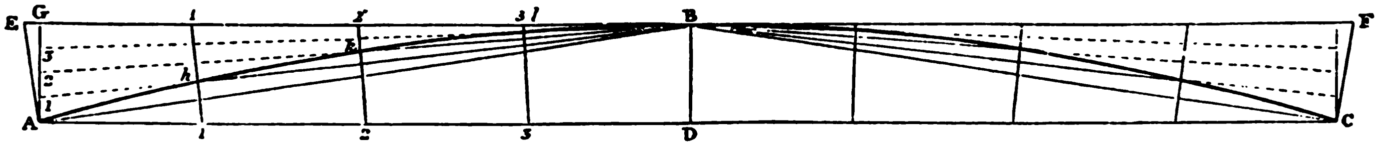


Fig. 21

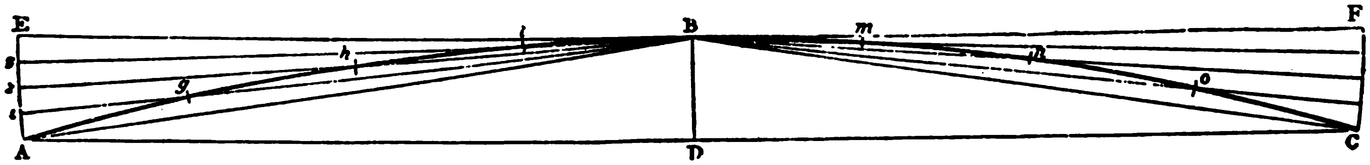


Fig. 22

A G into the same number of equal parts as A D or E B, numbering the divisions from A upwards, 1, 2, 3, etc.; and from the points 1, 2, and 3, draw lines to B; and the points of intersection of these, with the other lines at *h*, *k*, *l*, will be points in the curve required. Same with B C.

Another Method.—Let A C (Fig. 22) be the chord and D B the versed sine. Join A B, B C, and through B draw E F parallel to A C. From the center B, with the radius B A or B C, describe the arcs A E, C F, and divide them into any number of equal parts, as 1, 2, 3: from the divisions 1, 2, 3, draw radii to the center B, and divide each radius into the same number of equal parts as the arcs A E and C F; and the points *g*, *h*, *i*, *m*, *n*, *o*, thus obtained, are points in the required curve.

I will now pass from the comparatively simple problem of laying down and fairing the lines of a small craft to the more difficult one of laying down the lines of a large vessel constructed of wood.

Chapter II

2a. Laying Down Large Wooden Vessels

The drawings of a large vessel are prepared in exactly the manner those of a small craft are, and the names of various lines and parts shown on drawings are the same as given in my list and explanations that refer to small craft drawings. So it can be said that a mould loftsman able to understand and read drawings for a small craft will experience no difficulty in understanding and reading drawings of large vessels.

Figs. 23, 24, 25 are reproductions of lines and construction detail drawings that have appeared in recent issues of The Rudder. They will serve to clearly illustrate the way an experienced naval architect prepares vessel drawings.

2b. Brief Explanation of Lines Drawing Fig. 23

This is an illustration of a carefully prepared lines drawing of a 292-foot commercial schooner, and if you will compare this drawing with Fig. 1 lines drawing, you will note these minor points of difference in the manner in which some of the lines are marked.

1st.—Body plan is shown at center of profile view. This is for convenience, because when drawings are as large as the original of this one is, it is necessary to arrange views so that size of drawing is kept within dimensions convenient for handling.

For the same reasons diagonals shown below half-breadth water-line view, Fig. 1, are omitted from Fig. 23 drawing.

2d.—Ordinates at forward and after ends are closer together than those along middle portion of vessel.

This is done to facilitate fairing ends of vessel.

In large vessels there is a portion of middle body where shape and dimensions vary very slightly, and there are other portions at bow and stern where there is considerable change in both shape and dimensions.

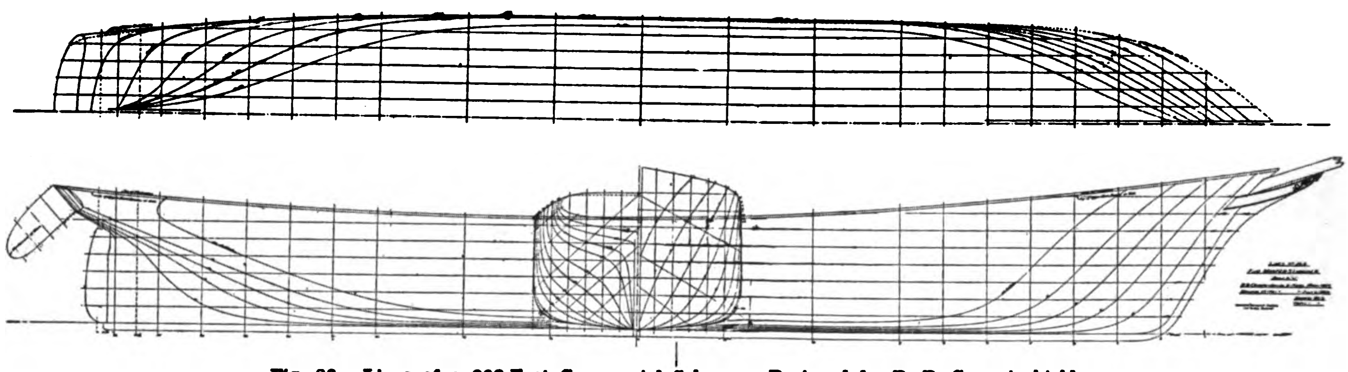


Fig. 23. Lines of a 292-Foot Commercial Schooner, Designed by B. B. Crowninshield

Wherever shape changes abruptly, it is usual for the designer to insure accuracy of lines by marking additional ordinates, one or more being placed between each two regularly spaced ordinates. On the Fig. 23 drawing four additional ordinates are spaced forward, each being placed one-half way between two regularly spaced ordinates, and aft there are placed five additional ordinates, three being at half intervals and two at quarter intervals.

3d.—The longitudinal water-line planes are evenly spaced from keel to sheer, the greater number of measurement points insuring greater accuracy.

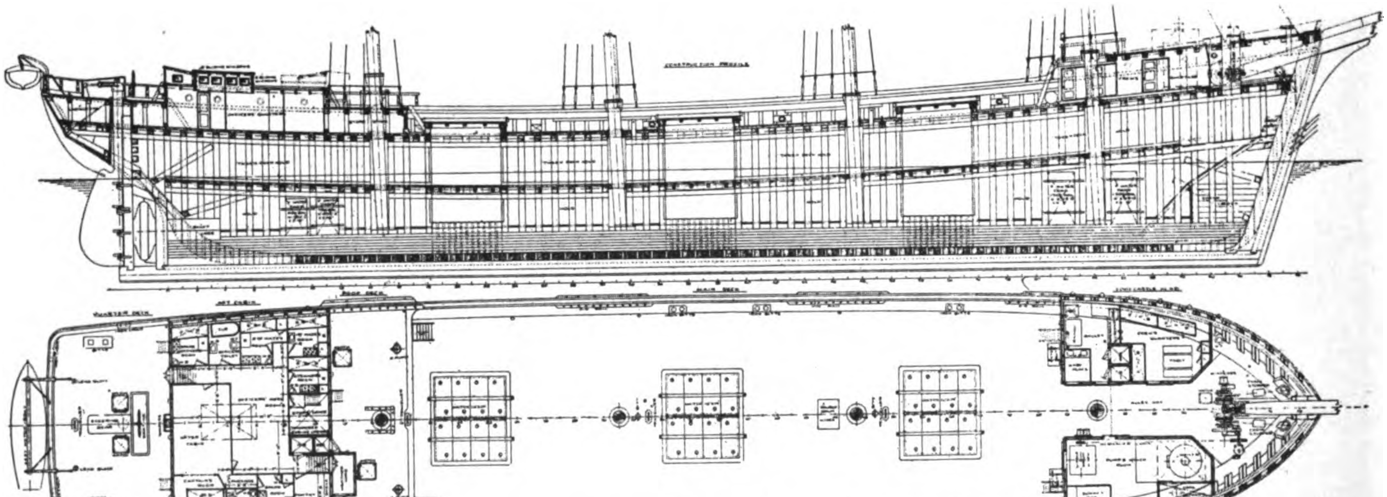


Fig. 24. Construction and Deck Plans of a 223-Foot Auxiliary Schooner, Designed by Cox & Stevens

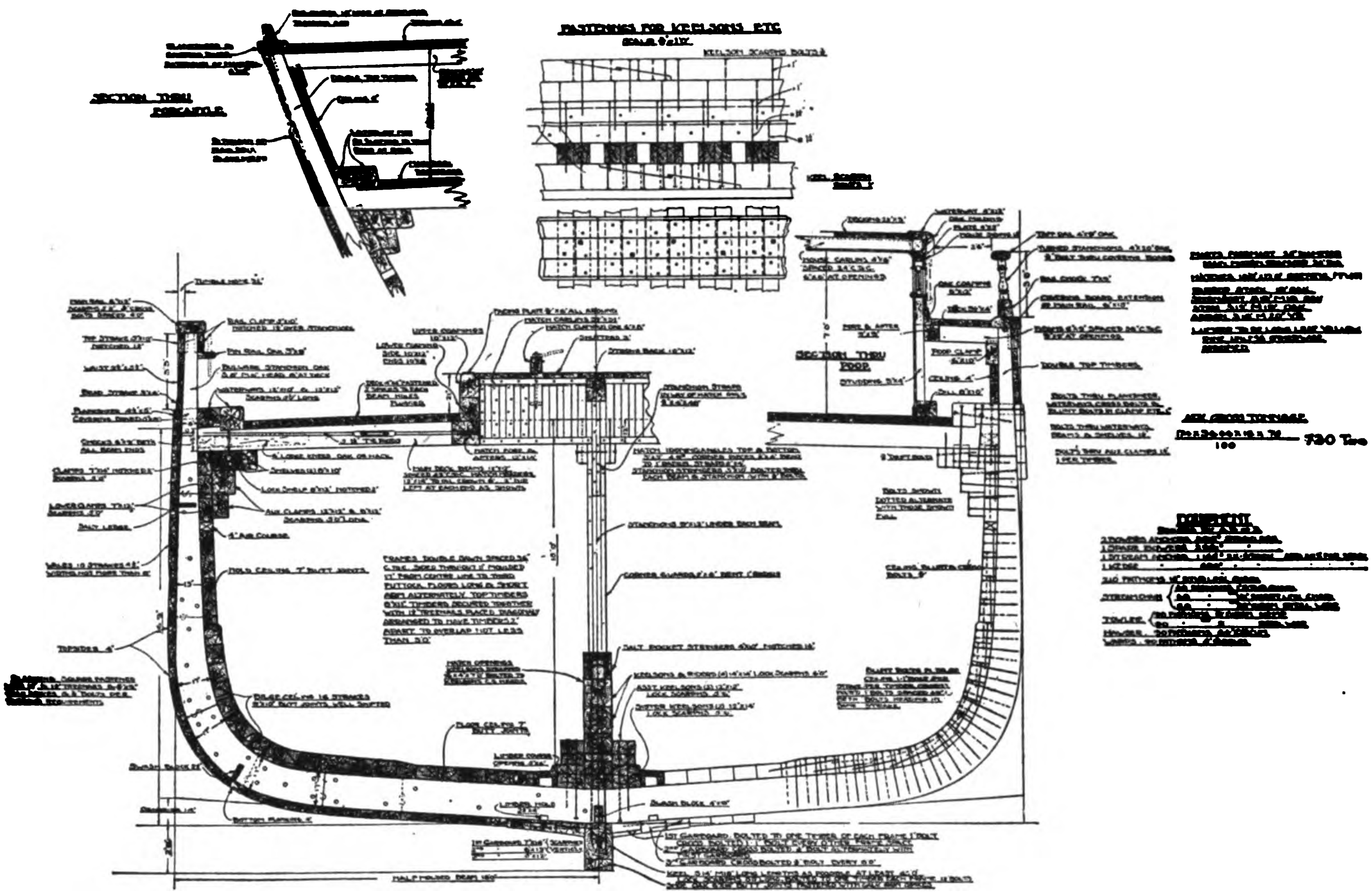


Fig. 25. Midship Section Construction 200-Foot Schooner, Designed by Cox & Stevens

2c. Method of Procedure When Laying Down Lines of a Large Vessel

When a mould loft floor is sufficiently large to allow the whole vessel to be laid down full size, at one time, the lines are laid down and faired in the manner smaller crafts lines are laid down and faired, but if the floor is not sufficiently large for doing this, the mould loftsman divides the vessel (longitudinally) into three parts and lays down each part separately.

The points of division, when this is done, are:

Bow portion: from bow to 8th ordinate from bow. (See Fig. 23.)

Midship portion: from 8th ordinate from bow to 9th ordinate from stern.

Stern portion: from stern to 9th ordinate from stern.

The named length of each part indicates length that should be "faired". The length actually laid down must in each case be greater by at least two ordinate spaces.

Thus the bow portion is laid down as extending from bow aft to 9th ordinate and faired to 8th ordinate from bow, the midship portion is laid down from 6th ordinate from bow aft to 7th ordinate from stern and faired from 8th ordinate from bow to 9th ordinate from stern; and the stern portion is laid down from 10th ordinate from stern and faired from 9th ordinate.

This procedure is necessary to insure that the three portions will fair individually and also when joined together.

The mould loft floor is prepared, measurements transferred to it and lines marked and faired in the manner already explained, but this important fact must be kept in mind: *As the frame of a large vessel is sawed to shape, it is necessary, after lines have been faired, to mark on profile and half-breadth water-line views lines to indicate the location of each and every frame, and then to carefully measure along these lines, transfer measurements to a large movable portion of floor, and lay out the shape of every frame.*

These frames are laid down to inside of planking, and frame measurements must be taken along lines that will indicate the standing edge, or widest part of each frame. As it is important that this be thoroughly understood, I will explain the point more fully.

Both outer (planking) and inner covering of (ceiling) frames of a vessel is put on in planks that extend (longitudinally) from bow to stern, and as these planks must be securely fastened to all frames they cross, it is necessary that they fit snugly against the full width of every frame.

If you will look at body plan Fig. 23 you will see that, except along a small portion of middle length, there is a variation in width of vessel and a difference in shape of each cross-section.

It is therefore apparent that a measurement taken along a line drawn where the after edge of a 6-inch wide frame is to be located will not be accurate for the position where forward edge of same frame is, or, in other words, each frame measurement is only accurate for one exact position, and this position is always indicated by a line marked where the widest part of each frame is located; which is the *after* edge of all forebody (forward of amidship) frames and the *forward* edge of all afterbody frames.

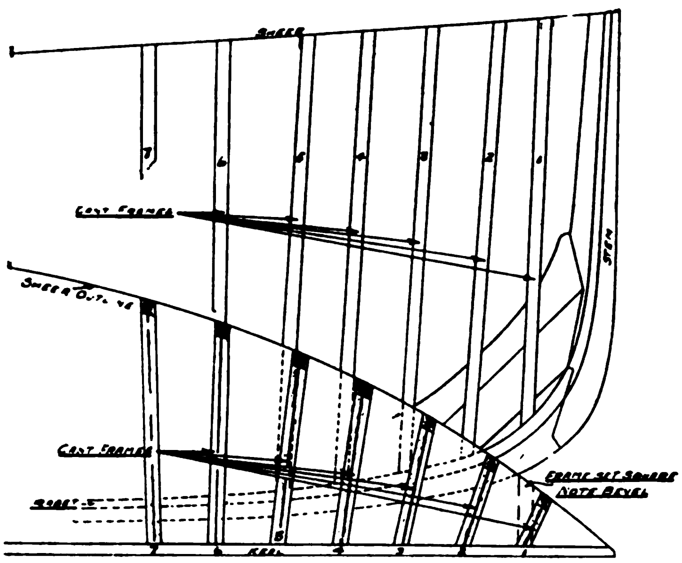


Fig. 26

Therefore, when laying out marks to indicate locations of frames it is essential that marks for frames ahead of midship be where the *after* edge of each frame is located, and those for frames aft of midship be where forward edge of each frame is located.

When shape of the widest edge of a frame is known, shape of narrowest edge can readily be obtained by using bevels. Method of getting these bevels will be explained after I have completed my explanation of location of frames.

2d. Locating the Frames

While frame locations and spacing (distance edge of one frame is from corresponding edge of adjacent one) are marked on construction drawing (see Figs. 24 and 25), it is necessary to keep in mind the fact that some of the forward and after frames do not set at right angles to center line of keel, and for this reason the mould loftsman must first mark location of all frames along center line of keel of half-breadth water-line view, and then using these marks as starting points, he marks the exact line of direction of each frame. After this has been done, the lines are transferred to profile view.

2e. Laying Out Lines of Direction of Forward and After Frames

For the purpose of making my explanation clear I have drawn Fig. 26.

Fig. 26 shows a portion of forward lines of a vessel and on it I show a few forward frames properly laid out to show their line of direction. These frames are termed *forward cant frames,* because they are "canted" forward of perpendicular.

At the extreme forward end of a vessel the sheer outline bends rather abruptly as it approaches the stem (note this line on Fig. 26) and this change in direction would necessitate a very large amount of beveling of frames located near to bow if frames were set at exact right angles to keel. The dot-and-dash-lined frame No. 1 is drawn to illustrate the amount of bevel No. 1 frame would have if it were set at right angles.

This bevel is a detriment, because it wastes material and reduces strength. If you will now take note of the lessened amount of bevel that frame No. 1 has when it is canted as shown by full shaded lines, you will readily understand the advantage of canting frames at extreme bow of a full-lined vessel. In addition to this, canting frames adds to strength of structure, because canted frames are better able to withstand the shock and strain of waves pounding against bow of vessel than right-angled ones.

In the days when wood ship-building was in its prime, it was considered proper to cant frames for a large portion of forward and after body, and, in fact, in some vessels all frames forward and aft of the "square" middle body were canted.

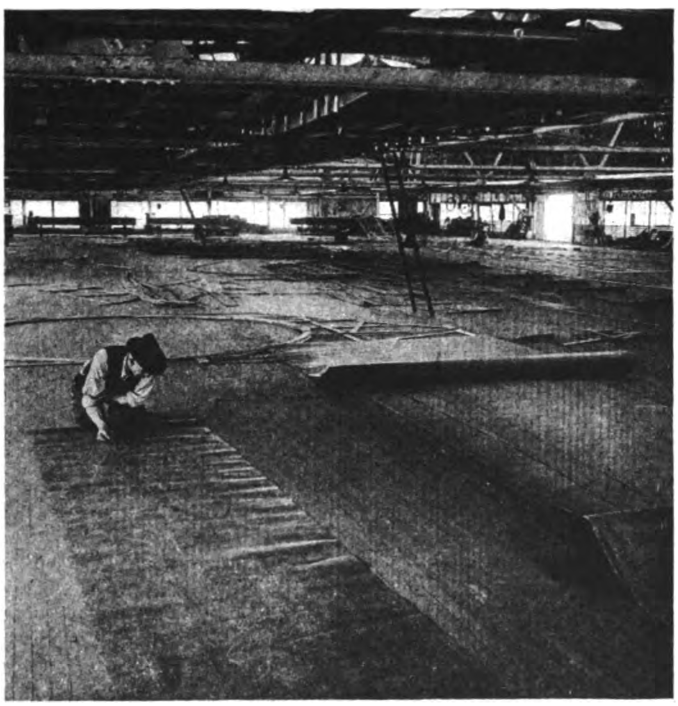


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Fig. 27. Making Full-Sized Paper Pattern

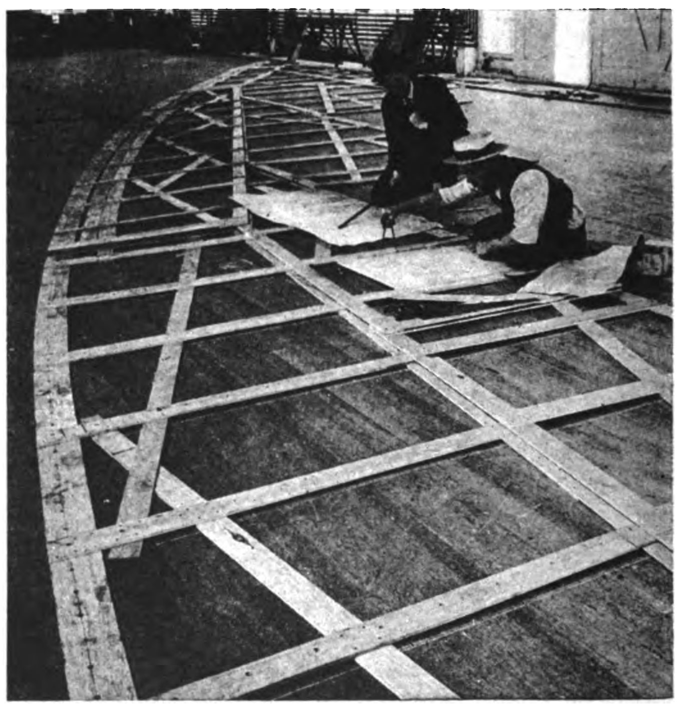

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Fig. 28. Template-Making on Mould Loft Floor

In these days, however, it is not considered necessary to cant more than six or seven bow frames and about the same number at stern.

The extreme bow frame is canted forward the most, and each succeeding frame aft of it is canted to a gradually lessening degree. On Fig. 26 I show six forward canted frames; note that each stands at a different angle, and note how the bevel at sheer is lessened by canting.

The point to keep in mind when locating inclination of cant frames is to incline each frame to a degree that will reduce bevel at sheer to a minimum. If bevel at sheer is reduced to a minimum, the bevel at all points between sheer and keel must be at a minimum. Of course canting frames does not change location at keel.

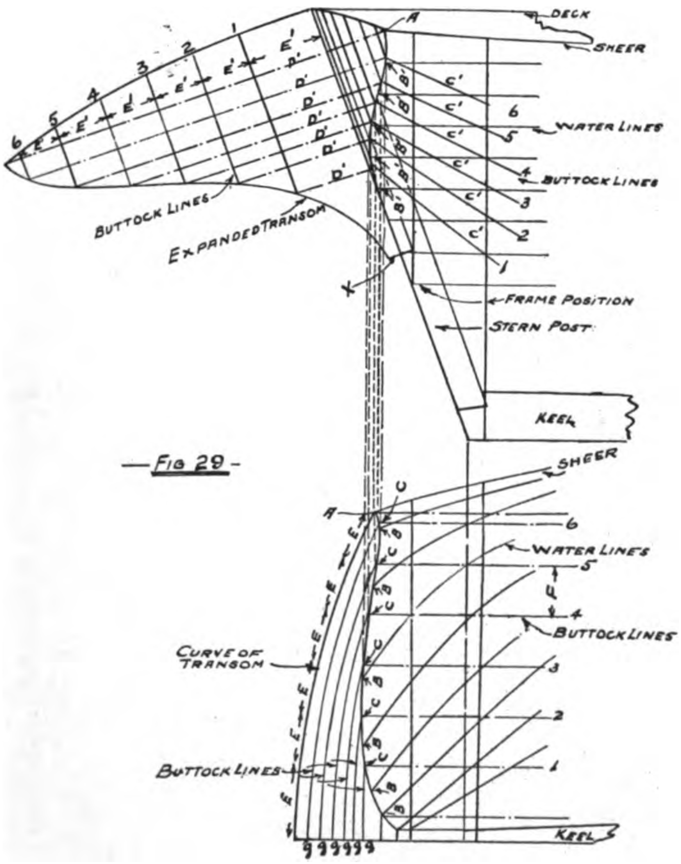
Aft the same condition prevails in all vessels that have a rounding stern at sheer, and when this occurs all frames along rounded portion of stern are canted *aft.* These are termed *after cant frames.*

2f. Laying Down Transom Stern

I will now explain one way to lay out shape of a transom stern that is inclined aft, has its after face rounded and is intended to be made of pieces of material bent to shape.

Fig. 29 is for the purpose of illustrating my explanation.

I have already explained that after the mould loftsman has laid down water-lines shapes, he marks diagonals and buttocks and by using the points of these lines as additional points, he fairs the vessel's lines. When laying out the transom this same procedure is followed, but as it is necessary, in this case, to consider the rounding face of transom and lay this round out as a flat surface, some additional work is necessary. On Fig. 29 is shown the stern buttock, water-lines, transom, and profile lines of a small vessel, each line being identified by name.



—Fig 29—

On the half-breadth water-line view of Fig. 29, the line marked "Curve of Transom" is a continuation of sheer outline and its shape is obtained from measurements given on table of offsets. To obtain the point at sheer on profile where transom outline will meet sheer, all that is necessary is to extend a vertical from point "A" on water-line plan to "A" on profile at sheer. The other points for profile outline of transom are obtained by transferring measurements taken across each water-line on transom outline laid out on body plan, to half-breadth water-line view, marking a curve to cut these points and then transferring the points where *buttocks* touch this outline up to the profile view.

B points on half-breadth water-line view are measurements obtained from transom outline on body plan and B1 are the same points transferred up to profile view.

Next the buttock lines laid out on both half-breadth water-line and profile views are made to terminate where each one cuts transom outline B on profile and B1 on half-breadth water-line view.

The points C and C1 indicate termination of buttocks.

From the C1 points parallel lines, marked at right angles to center line of face of transom, are drawn (the dot and dash lines marked D1) and then the straight buttock lines, 1, 2, 3, 4, 5, 6, are marked at right angles to the D1 lines, but in place of marking there the exact distance buttocks are apart on *half-breadth water-line view,* they must be marked the distance they are apart *measured along the curved face of transom,* which is slightly greater than distance F.

The points of meeting of the D1 and E1 lines will be points for expanded transom outline and a curved line drawn to cut all points will give shape of expanded transom.

The accuracy of transom can be proven by drawing curved lines G across transom view on half-breadth water-lines, carefully measuring along each curve and transferring the measurements to D1 lines across transom. If accurate each measure should check with its D1 line on transom.

Bevels of transom are obtained by measuring in the manner explained in paragraph on bevels of frames, but you must bear in mind that when taking bevels, the bevels must be taken from transom when in its place in vessel, and not from expanded transom.

In a vessel like the one shown on Fig. 23, the stern is framed and planked, the stern framing beginning with a pair of cant frames, called Fashion Pieces, that form the outline (shape) of stern. These Fashion Pieces are then connected by wing and deck transoms that extend transversely across stern and then the wing and deck transoms are connected by vertical counter timbers spaced proper distances apart and having the desired curve. The planking of stern extends transversely across from Fashion Piece to Fashion Piece. Measurements for transom frame constructed in this manner are obtained from Cross Section Plan in the same manner that other frame measurements are obtained.

At present time many wood vessels are designed with an elliptical stern. As this type of stern is also extensively used on steel vessels, I will explain the way to lay out an elliptical stern when I explain Laying Down a Steel Vessel.

I will next explain how the bevels of frame timbers are obtained and templates of their shape made.

2g. Obtaining Frame Timber Bevels

Every frame of a wooden vessel must be laid out full size, either on mould loft floor, or on a movable board platform, and the bevels along outer face of each frame must be accurately determined and laid out. This is necessary to enable the ship-carpenters to properly shape and bevel the frames.

In all vessels the frame timbers are spaced a certain distance apart and this distance is the same for all frames except cants; but owing to the fact that a vessel narrows at bow and stern, and from deck to keel, the bevel on outside of each frame varies from deck to keel and no two frames, except those along the middle square body, have the same bevel. This being the case, it is necessary for mould loftsman to record the bevels of each frame

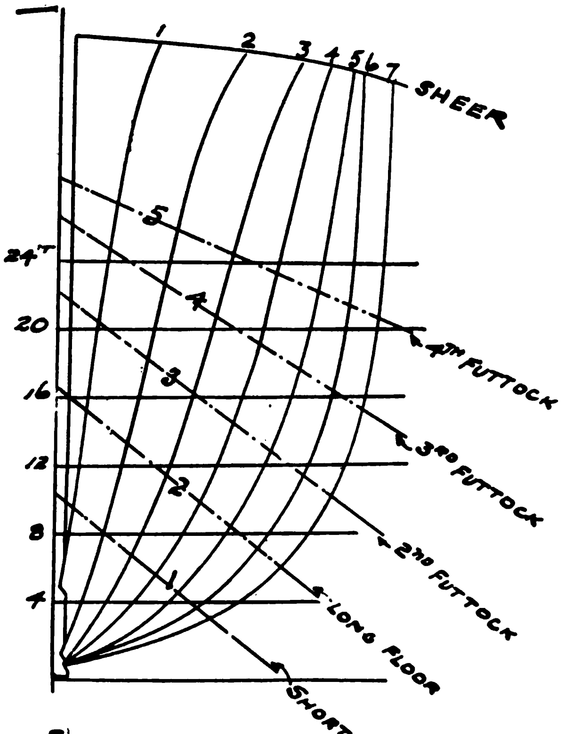


FIG 34

in such a manner that the ship-carpenter can use his record as a guide for beveling frames before they are assembled and put in place in vessel.

The way frame timber bevels are taken and recorded is explained below.

On Fig. 34 I show a few of the forward body frames of a wooden vessel (as laid down on mould loft floor) and for the purpose of making my explanation clear I give you the information that frame spacing (from center to center) is 36 inches. This is the "room and space."

It stands to reason that if each frame outline shown on a body plan of vessel is a known equal distance apart (in this case 36 inches) the distance from outline shape of one frame to outline shape of the next will accurately represent the amount of decrease in width of vessel at that point and in that distance (36 inches). Therefore, knowing the room and space (36 inches in this case), all that mould loftsman has to do is to lay off the room and space distance on a board and then by measuring distance between frame outlines, at certain selected points and along certain designated lines, and using this measure as a guide for adjusting a bevel, he can accurately lay out frame bevels and transfer them to a bevel board.

The tools used for setting down bevels are an adjustable armed bevel and board made as shown at left hand of Fig. 30. This bevel is mounted on a board having a width equal to room and space, in the manner shown on illustration. The bevel is placed about ¾ inch above board it is mounted on, thus permitting a ¾-inch thick piece of wood to be inserted under bevel with its edge against guide to which movable arm is attached. On illustration a ¾-inch piece of wood is shown in position under movable arm. With these tools and a rule the mould loftsman takes his bevels in this manner.

The mould loftsman has already laid out and faired the lines, taken off thickness of planking and marked the full-sized outline shapes of all frames on floor. He next lays out on the frame outlines, at proper inclinations and at proper positions, a certain number of diagonal lines, these lines being marked as near as possible at right angles to frame outlines and at positions where end of each futtock of frames will come.

On Fig. 34 these diagonal lines are marked and at edge of outline I have also marked the name of futtock that will end at each line. It is along these lines that distance between frame outlines is measured.

Bevels taken along each diagonal are usually marked on the same piece of wood, though there may be three or more pieces used for a diagonal, one being for forward and after cant frames, another for forebody frames, another for square body frames, and another for after body

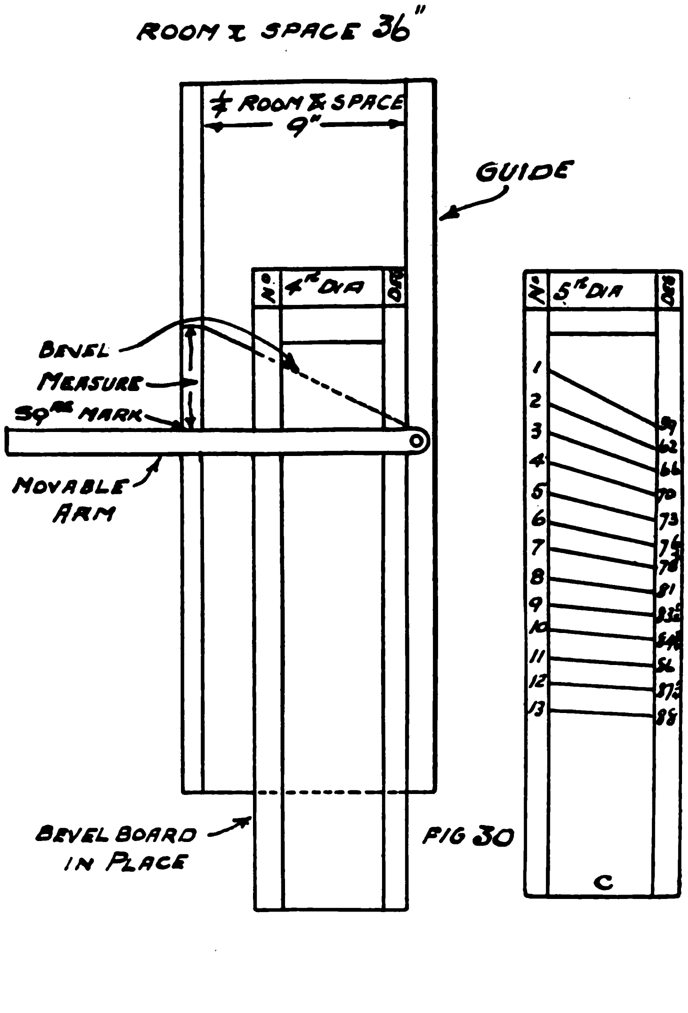


FIG 30

frames. I will now take and transfer some bevels on "5th diagonal."

We know that the room and space is 36 inches, therefore my room and space board is made either 36 inches wide, or a multiple of 36 (say one-fourth, or 9 inches).

I place a piece of wood in position under movable arm, mark a perfectly square line across its head and then write on top of this board, "5th diagonal". Next I mark plumb lines an inch or so from each edge of this piece of wood. These marks make a margin along edges that can be used for marking frame and degree-number against each bevel. I next measure *exact* distance from frame No. 1 to frame No. 2, measured along 5th diagonal line, and if my adjustable bevel and its board is full room and space width I transfer distance between frame measure to room and space board and at the named distance from square mark across that board I make a mark. If now the adjustable arm is moved to cut this mark and its edge used as a guide for marking an inclination line across the piece of wood placed under bevel, the exact bevel of frame No. 1 along 5th diagonal, which is located at 4th futtock head, will be indicated. Distance from No. 2 frame to No. 3 frame is measured and transferred in like manner, and so on until the first frame of square body is reached.

On Fig. 30 is shown 5th diagonal bevel board completed. The numeral against each bevel indicates number of frame.

Should, however, the adjustable bevel be on a board having a width that is less than the room and space, then the actual measure taken between frames must be reduced in same proportion that width of board is reduced. Thus, if width of board is one-fourth room and space measure, then between frames measurements must be reduced to one-fourth before transferring.

In a modern shipyard all wooden frames are beveled while being sawed to shape and as the machine (bandsaw or adjustable head beveler) is graduated in degrees, it is usual for mould loftsman to mark its exact angle against each bevel on a bevel board.

These marks are made along one edge of board so that the completed board has the appearance shown on *C* of Fig. 30. The bevels are, of course, the angle between bevel lines and perpendicular edge of bevel board.

Bevels are taken along sheer, along each diagonal and at keel, as it has been found that bevels taken at this number of points, along a frame, will enable the whole frame to be very accurately beveled.

2h. Making Templates of Parts of a Wooden Vessel's Construction

I will now explain and illustrate the way templates of the parts of a large vessel are made in a mould loft. While it is possible to make solid templates of stem, deadwood, etc., of a small vessel's parts, it would not be satisfactory to make solid templates of parts of a large vessel, because their weight would be excessive. Templates of parts of construction of a large vessel are usually skeleton templates composed of narrow strips of light material framed together in such a manner that while template will be as light as possible, all needed lines will come on a solid portion of template.

Large vessel templates of stem, after deadwood, sternpost, transom and a floor mould are shown on Figs. 31, 32, 33. A study of these templates will serve to explain construction of all templates except the floor template better than a lengthy written explanation will, so it is only necessary to call your attention to these things.

On all stem, deadwood, and stern-post templates the scarphs are accurately fitted and the outlines made exact to shapes laid down on mould loft floor. In addition to this the pieces of template are laid out in such a manner that all necessary lines, like bearding, rabbet and cutting down lines, can be marked along template in their proper position; unless, as is sometimes done, the mould loftsman makes separate rabbet, bearding and cutting down outline templates.

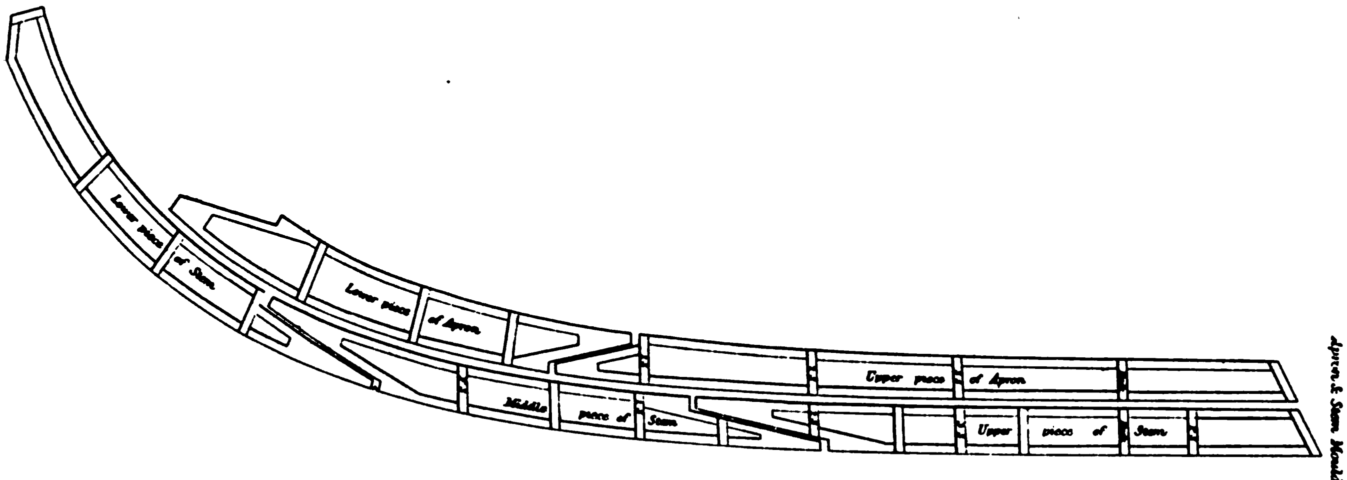


Fig. 31

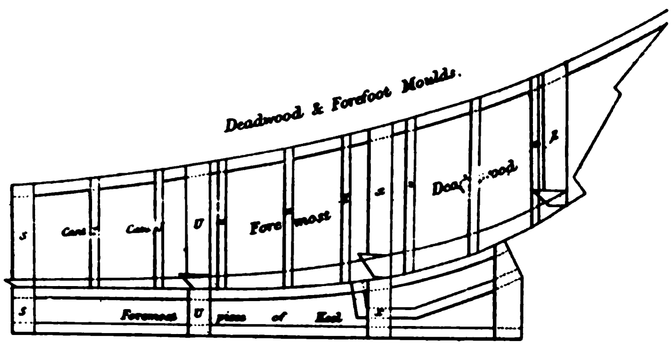


Fig. 32

Thus the several stem templates fit together and these in their turn fit to forward deadwood template. This also applies to stern-post and after deadwood.

Regarding keel templates, it is seldom necessary to do more than make templates of scarphs and give length of pieces, because the keel is usually composed of straight sticks of timber scarphed together.

In cases where keel is curved, the amount of curve is measured, on mould loft floor, at certain indicated frames, and these measurements used for marking out keel.

It should be kept in mind that all frame timbers of large wooden vessels are beveled inside and outside because both the outer planking and inside ceiling must "fay" to frames before being fastened.

In addition to this, surfaces of all hanging and lodge knees that fit against ceiling require beveling, and as these bevels can be obtained from frame bevels at points where they are located, it is advisable to make bevel boards to indicate bevels of these knees, because, in a modern shipyard, the majority of the knees can be beveled by beveling machines, thus saving a great deal of hand labor.

2i. Making Templates of Frame

In order to get each frame's shape accurately it is

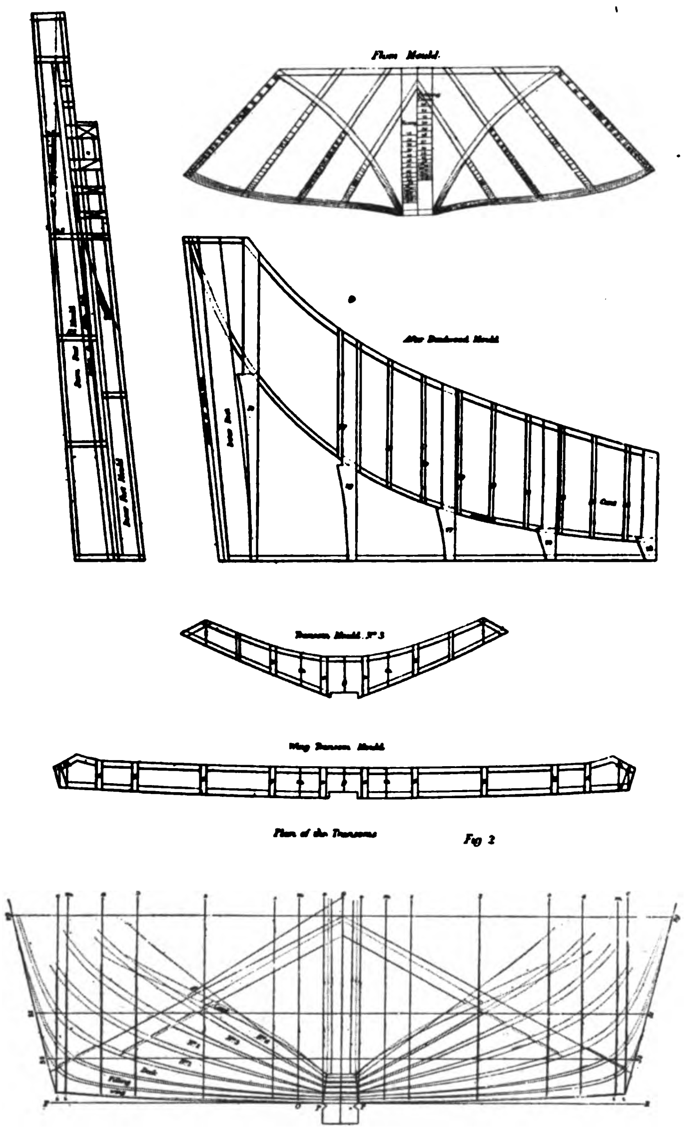


Fig. 33

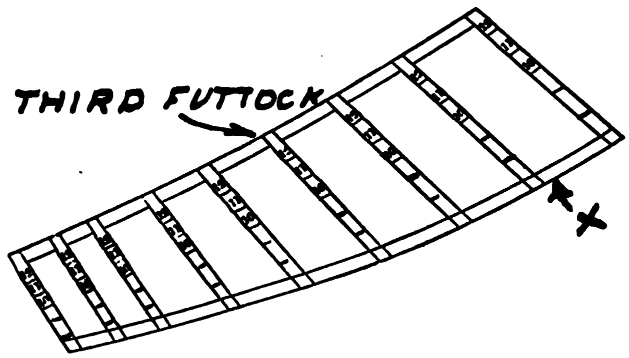


Fig. 33A

necessary that the men laying out the frames have an accurate set of templates or patterns to guide them. These patterns can be made in either of the following ways:

(a) A full-sized pattern of the outline shape of every frame can be made.

(b) Skeleton templates on which can be marked lines to indicate the shape of each floor and futtock.

To make a full-size pattern of outline shape of every frame will entail a large amount of work and the size of pattern would be too large for convenient handling. In all modern shipyards the practice is to make skeleton templates and mark on each a number of lines that will indicate the shapes of futtocks or floors of a number of adjacent frames.

On Fig. 33 is shown illustrations of some of these templates, and Fig. 33A illustrates third futtock template for a certain number of frames (seven).

The inner line on this illustration indicates shape of third futtock for No. 13 frame, and the outer line marked with cross indicates shape of third futtock of No. 7 frame, and each set of lines marked across the connecting ribbands indicates shape of third futtock of a frame between 13 and 7; thus the series of lines marked 12 give shape of third futtock of twelfth frame, those marked 11 shape of third futtock of eleventh frame, and so on. You can readily understand that templates of this kind are easy to make and handle and the cost of making them is far less than cost of making complete templates for each separate frame.

Suppose a ship-carpenter is going to lay out frame No. 12 of third futtock. He places the third futtock template over his material, being careful to allow sufficient material inside of the twelve lines for moulded measure of frame, and tacks template to material. He then drives a brad alongside each 12 mark on a cross batten and removes template. A ribband is next bent against the brad and outline of frame futtock can be marked by using the ribband as a guide. To get inner shape of futtock the carpenter sets a pair of compasses to moulded measure of futtock, pricks off distance from batten, drives another lot of brads in the prick marks, and after bending a batten to these brads and using it as a guide he marks inner shape of futtock. All futtock templates are made sufficiently long to allow material for cutting and fitting futtocks together when assembling a frame. It is in this manner that all of the frame templates are made in the mould loft.

On Fig. 33 is shown the shapes of floor mould, transom mould and wing transom mould, also plan of transoms of a large vessel as laid down in the mould loft.

Chapter III

3a. Laying Down a Steel Vessel

I will now explain mould loft work that has to be done in connection with laying down a steel vessel. When a vessel is to be constructed of steel the mould loftsmen have to lay out a number of construction details and make templates that are not required when a vessel is to be constructed of wood, and in addition to this it is very necessary that every plate, butt strap and all riveted fastenings be laid out accurately on all principal templates.

As it is not possible to accurately lay out the plating that covers the frames of a steel vessel without having an exact copy of the outside form of vessel the usual practice in a modern shipyard is to make a scale model of vessel and mark on it the exact plating lines with all butts and fastenings in proper positions. On Fig. 34 is shown such a model with plating lines, butts, etc., marked.

A little further along I will fully explain the way these lines are developed and marked.

The actual work of laying down and fairing the lines of a steel vessel is done in the manner already explained for wood construction, except that a few modifications are made necessary by reason of the change from wood to steel. These modifications I will now explain.

1st.—After lines are faired and position of each frame marked on longitudinal plans, outlines of frame must be accurately laid out on a separate movable platform, called a scrieve board. The scrieve board itself is composed of perfectly jointed and smoothed boards fastened on a framework of timbers sufficiently heavy to prevent boards warping or separating. Scrieve boards are smoothed, painted with several coats of dull black paint, and then the lines marked on board are scrieved, or cut, into the wood with a very fine rase knife. Thus every line will stand out distinct and clear on the dull black background of board.

As the board is movable it can be, and is, always moved to whatever place it is needed when parts are being got out.

2d.—After frame outlines are marked on scrieve board these additional lines are laid out in proper position relative to the frames they cross:

(a) Lines to indicate location of top of double bottom and points where double bottom plating touches frame.

(b) Lines to indicate positions of longitudinals and intercostals that support double bottom.

(c) Lines to indicate positions of longitudinal bunker bulkheads.

(d) Lines to indicate positions of edges of shell plating.

(e) Lines to indicate locations of longitudinal stringers.

(f) Lines to indicate locations of transverse bulkhead stiffeners, plating seams, etc.

(g) Lines to indicate shape and location of deck beams.

With these lines marked the scrieve board can be

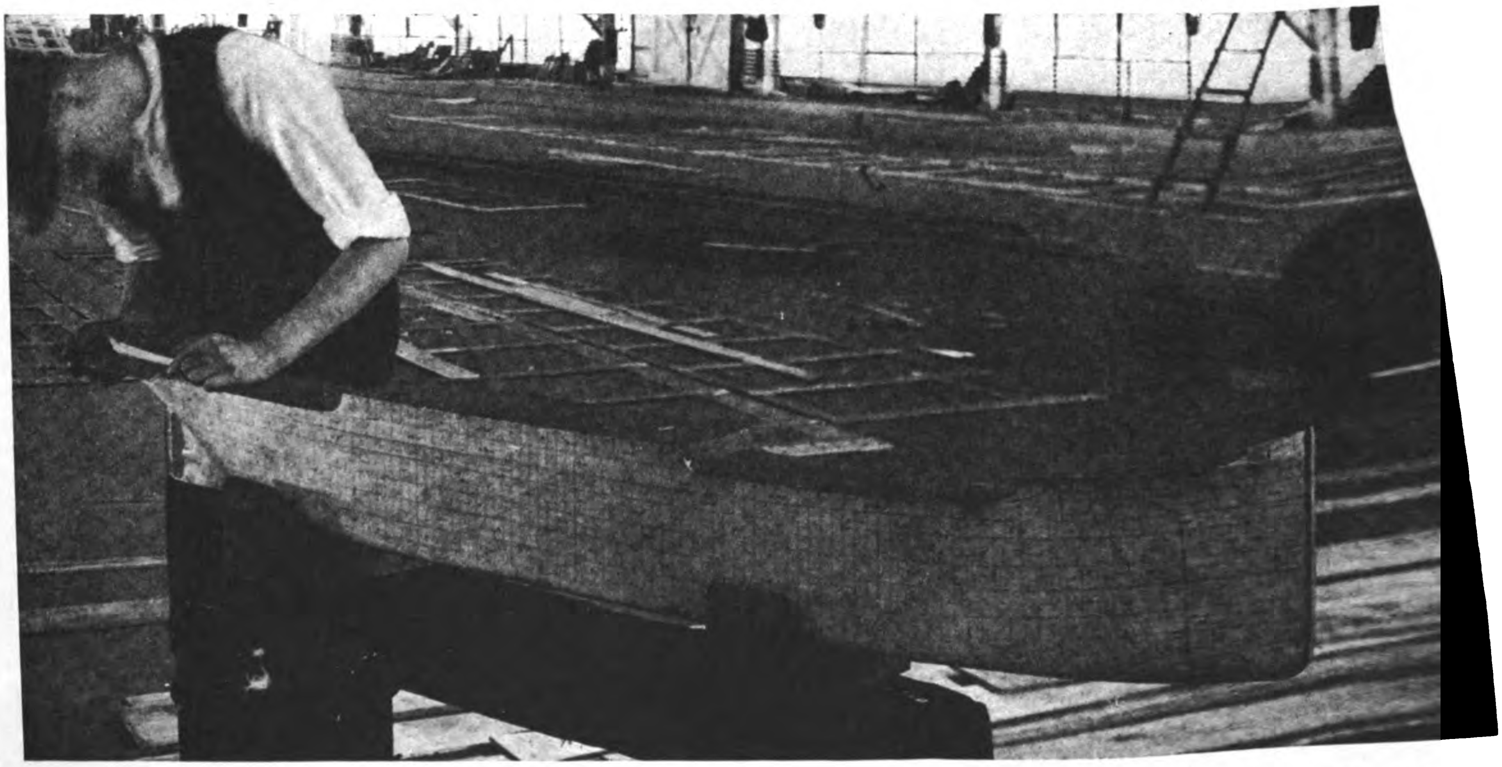


Fig. 34. Scale Model of Steel Vessel

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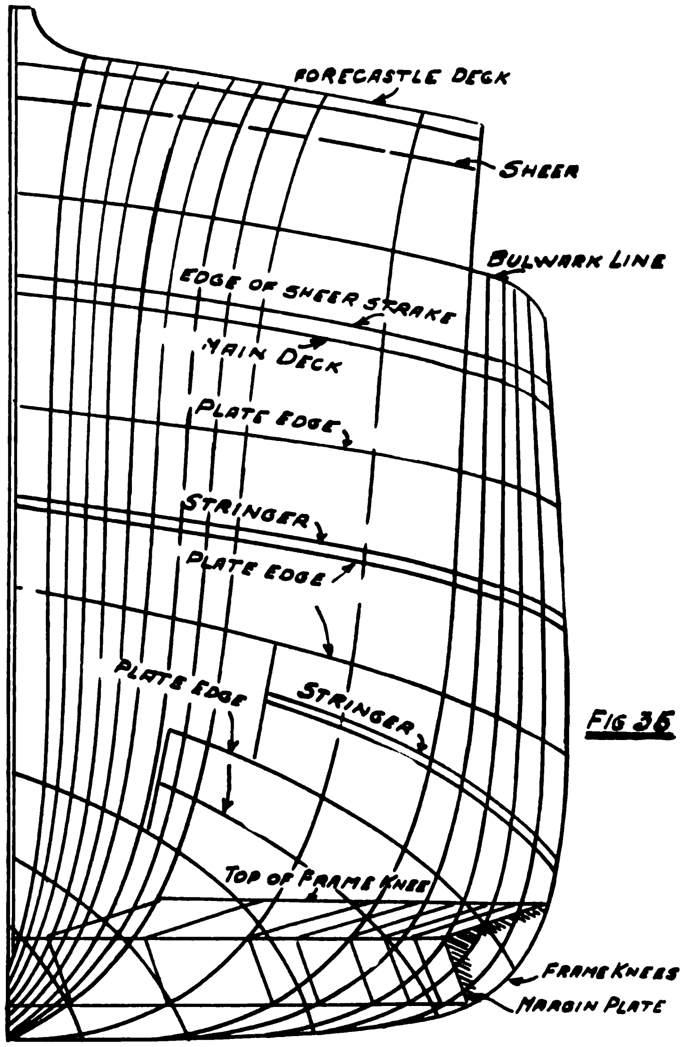
used as a guide for the workmen when bending and beveling frames, and getting out and assembling the floor plates and other materials.

On Fig. 35 I show half of a forebody scrieve board with various lines marked for identification, but some of the frame outlines have been erased from illustration in order to make the remaining lines appear distinct.

Describing the manner in which measurements for laying out the lines shown on Fig. 35 are obtained.

3b. Frame Outline Shapes

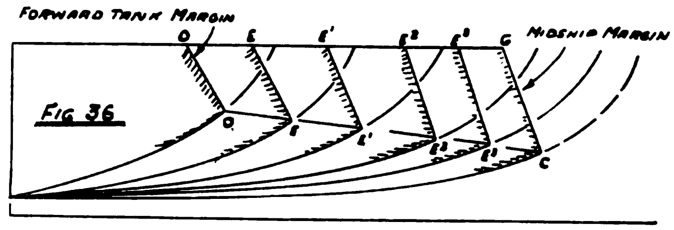
Measurements for frame outline shapes are obtained from profile and half-breadth water-line plans laid out on mould loft floor. After lines have been laid down and faired the mould loftsman marks vertical lines on



profile and half-breadth views to indicate where each frame is located, and then by taking measurements along these lines, transferring measurements to proper locations on scrieve board and bending a batten to the measurement points, the outline shape of each frame can be accurately marked. Of course the frame shapes marked on scrieve board must be to *outside* of frame (inside of shell plating) and therefore if lines laid down on mould loft floor are to outside of plating the thickness of plating must be taken off when laying out frame outlines. Method of doing this has been described in a previous part.

(a) *Inner Bottom Height and Width Lines*

The lines that indicate height of inner bottom are laid out from measurements taken from construction details on profile view of lines laid out on mould loft floor. The longitudinal construction details at center line of keel are shown on one of the original scale drawings supplied by designer, and it is from measures obtained from this drawing that the mould loftsman obtains points for laying out construction details on mould loft floor.



(b) *Width of Double Bottom Lines*

Width of double bottom is generally indicated on construction drawings, but if it is not it can be laid out by marking the spread or width of bottom at forward and after ends and then joining the two by a fair longitudinal line. The points where this line joins the top of double bottom line will indicate double bottom width at each section and will also indicate location of top of margin plate that forms edge of double bottom. This margin plate is indicated on Fig. 36. The points and measurements required for laying out details can be obtained from the designer's construction drawings, but the lines of plating (shell plating) cannot be indicated until after plating has been laid out on a scale model and faired on an expansion plan.

3c. An Expansion Plan Described

An expansion plan of shell plating of a vessel shows the lines of plating laid out as a plane surface. To draw an expansion plan on mould loft floor it is necessary to first lay out profile outline of keel stem and stern-post and to mark on it the proper locations of each ordinate (ordinate shown on lines drawing of vessel) or of each frame. Next it is necessary to carefully measure *girth* of vessel from rabbet of keel to sheer at each ordinate or frame and transfer these measurements to corresponding ordinate or frame line on expansion drawing. A curved line drawn to cut points marked where each girth measure ends will complete the expansion outline of shell plating. On Fig. 37 is shown a portion of bow expansion plan of shell plating of a vessel.

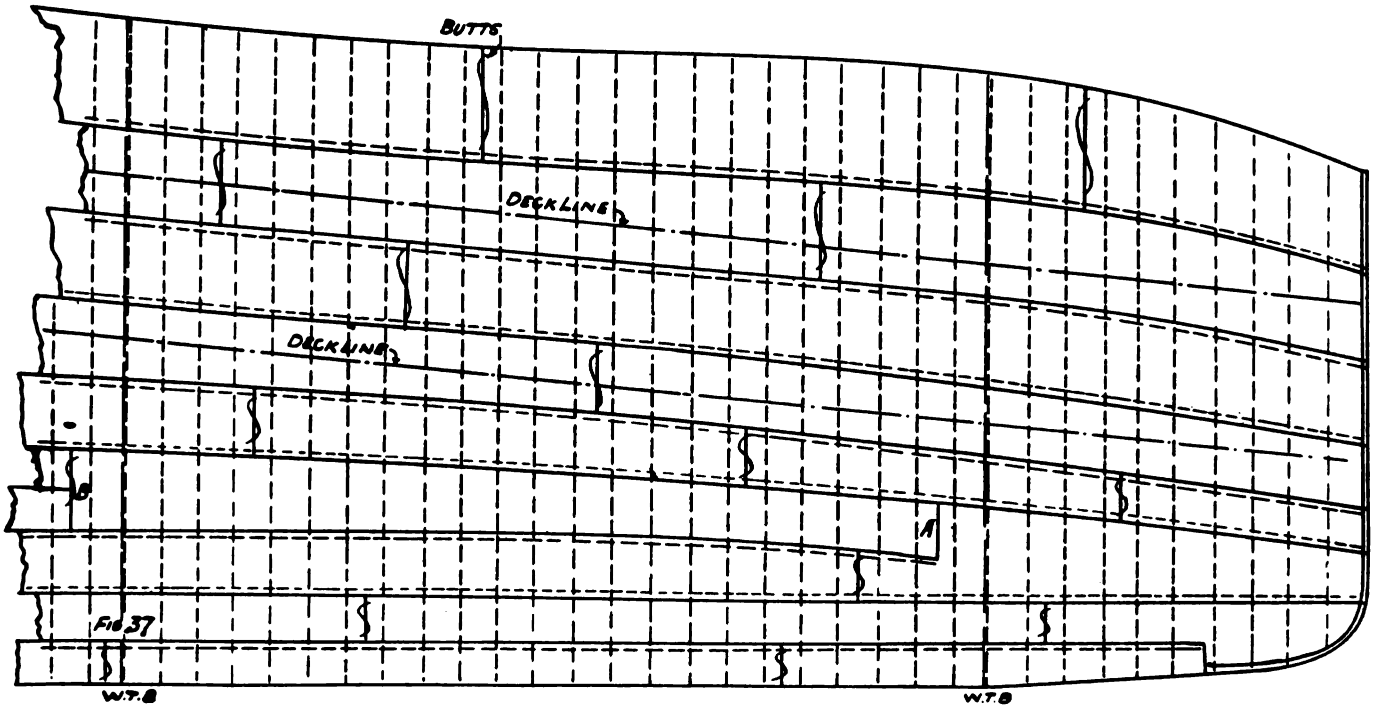
The lines that each shell plate will follow are obtained from plating lines laid out on a scale model of the kind shown on Fig. 34. It therefore is necessary that the mould loftsman make a scale half-model of vessel. One way to do this is described below.

3d. To Make a Scale. Half-Model

Scale half-models used by mould loftsmen are generally made of layers of soft wood glued together and then shaped exactly like hull of vessel is to be shaped.

Making a model is not difficult if work is done in proper order.

The easiest way to make a scale model is to glue together a sufficient number of pieces of soft pine in such a manner that the glued seams will run longitudinally, and be the same distance apart that water-lines shown on



lines drawing are, and if one seam (the L.W.L. one) is selected and surface of wood stained before it is glued the stain will show along joint and thus you will have one line (the L.W.L.) to use as a guide when shaping model.

After the glued pieces of wood are thoroughly set the side that will become back of model, or center line of vessel, is properly trued and jointed, care being taken to keep its surface at right angles to glued seams.

Next on this trued-up surface there is marked the longitudinal outline of vessel as it appears on profile view of lines drawing. The lines that must appear are,

Ordinate lines,
Outline of keel, stem and stern,
Rabbet line at stem, along keel and along stern,
Sheer line and lines of topgallant forecastle, poop, etc.

When these lines have been marked the model material is sawed and cut down to profile outline marks, care being taken to exactly follow outlines on model.

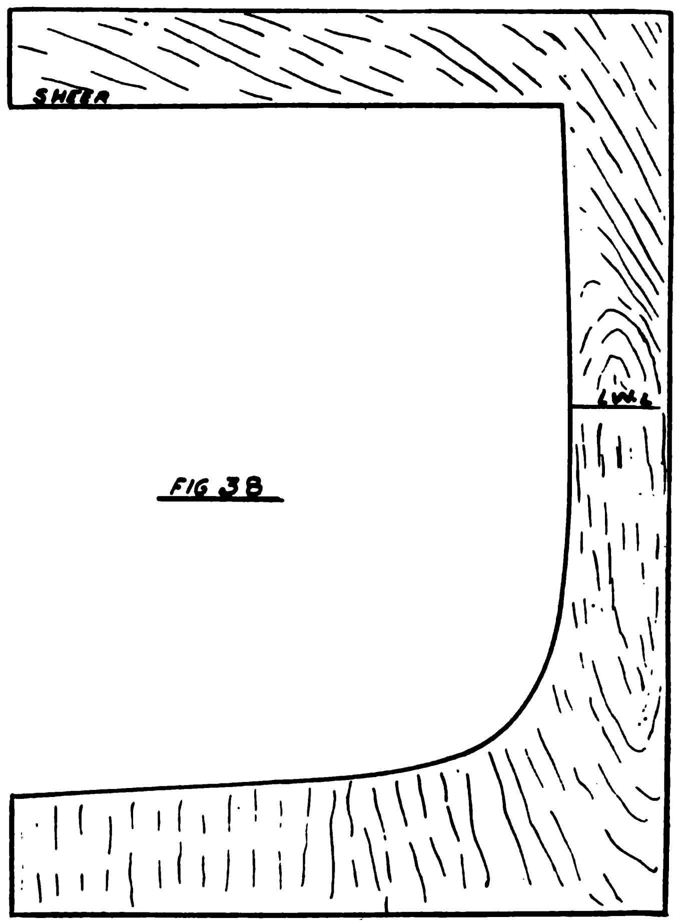
The next work is to fair the portion of model material that will become the sheer or deck and make it exactly square with (back) face on which profile outline is marked. This is done with a plane, spokeshave and files.

When deck surface is fair all ordinate lines used for marking out model are carried across deck surface and then the exact half-width measures at deck are transferred to ordinate lines, and if a batten is bent to cut the points it will be an easy matter to correctly mark deck outline shape.

When deck outline shape is marked the material outside of line is cut away and model roughed out ready for shaping, care being taken not to cut away too much material.

Next it is necessary to make hollow templates to indicate shape of model at each ordinate position. These templates are made from measurements obtained from body plan and are reproductions of cross-sections except that the cross-section outline shape is indicated by cutting away template material. On Fig. 38 one of the templates is shown and as I have indicated on illustration the various points and details no further explanation is necessary.

Templates to indicate shape of vessel at each ordinate are required and as soon as they are made the actual shaping of model can be done.



To accurately shape model all that is necessary is to take one of the templates and cut away surplus material on outside and bottom surfaces of model until hollow portion of template fits closely to model, *along a line that extends from proper ordinate marked across deck to same ordinate mark across keel.*

Each template is fitted carefully in its place and then if the surplus material between template positions (ordinate positions) is cut away until the whole surface of model is fair the model will be shaped exactly in accordance with shape of lines shown on drawing. Great care must be taken both when fitting hollow templates and when removing surplus material between template positions not to cut away too much material, and of course the last fairing, or smoothing of surface of model must be done very carefully with files and sandpaper, and lines faired by using a chalked batten.

When the model is fair all ordinate lines are carried around surface of model from sheer to keel and then all frames are marked across back and deck and around surface of model.

When frames are marked the plating lines can be laid out. Frame and plating lines are clearly shown on model Fig. 34.

3e. Laying Out Plating Lines on Model

As the number of plates and width of each is always shown on midship drawing of design it is an easy matter, especially if model is made to same scale as drawing, to transfer points for edges of plates from drawing to midship section position on model.

In general, the designer lays out plating edges to clear longitudinals and also takes care to select widths of plates that can be obtained and handled by the builders.

The best method of transferring widths of plates at midship section is to bend a very light batten around girth line on drawing, mark on it the exact location of each plate edge and then by removing batten from drawing and bending it around midship section of model the exact position of each plate edge can be accurately marked on model. The longitudinal lines of plating edges can be marked in this manner.

First lay off keel plate and garboard strake edge, as near as possible parallel to middle line of vessel. Next lay off two strakes of plating near to the L.W.L., and after this is done lay off the sheer strake.

When running these lines it is very necessary to use a properly proportioned batten that will not bend edgeways, and to make sure that batten lies flat on model for its whole length because it is only by doing this that straight-lined plates are obtained. Bear in mind that the fewer "sketch" plates there are (plates that have to be cut with curved edges) the lighter the labor of getting out plates will be.

In cases when a bilge keel is to be fitted it is necessary to lay out the line bilge keel will follow and then to locate plating edge in such positions that bilge keel will not have to cross a plate edge.

As plates approach stem and stern it will be necessary to either reduce their width, or else to stop some of them and thus have one or two plates less at ends than at midship. In general it will be found that a slight reduction in width of plates can be made at ends of vessel but the greater portion of reduction in width owing to reduced girth of vessel at these points will have to be obtained by dropping a strake of plating. This can be done in either the *A* or *B* way shown on Fig. 37.

A shows two adjacent strakes stopped at a point where their combined width has narrowed to width of one full strake, and from this point on one strake of plating is run to bow or stern as the case may be.

On *B* an extra plate, called a stealer, is introduced to make up the additional width required to insure fair plating edges without too great a reduction in width.

Having laid out the principal plates, the intermediate ones can be run in fair lines without difficulty.

When plating edge lines have been marked on model it is necessary to test their accuracy by reproducing them in proper position on the full-sized expansion plan laid out on mould loft floor. This is necessary because the model being so much smaller than full-sized vessel it is difficult to observe slight inaccuracies. So girth measures and plate-edge locations are carefully measured on model and transferred to proper position on full-sized expansion plan and then each plate edge line is laid out and faired, if it is found necessary to do so.

When plate edges are fair, the butt locations must be selected and butts marked on both the expansion plan and model.

Butt locations must be selected in accordance with these rules:

(a) There must be at least three full strakes between two butts coming in same frame space, and at least one full strake between butts in adjacent frame spaces.

(b) Butts must be laid out so as to avoid a diagonal line of butts from sheer to keel. The best method is to have butts form an irregular line from keel to sheer and the longitudinal distribution of butts on each succeeding strake should be as far apart as possible.

Plates should be worked in as long lengths as practicable thus reducing number of butts to a minimum.

If shell plating is properly laid out the largest portion of side and bottom plates will have straight-line edges, and templates of their shapes can be made without "mocking up". There will, however, be some plates, especially at ends and around shaft boss around stern, that cannot be developed without reproducing the curvature and

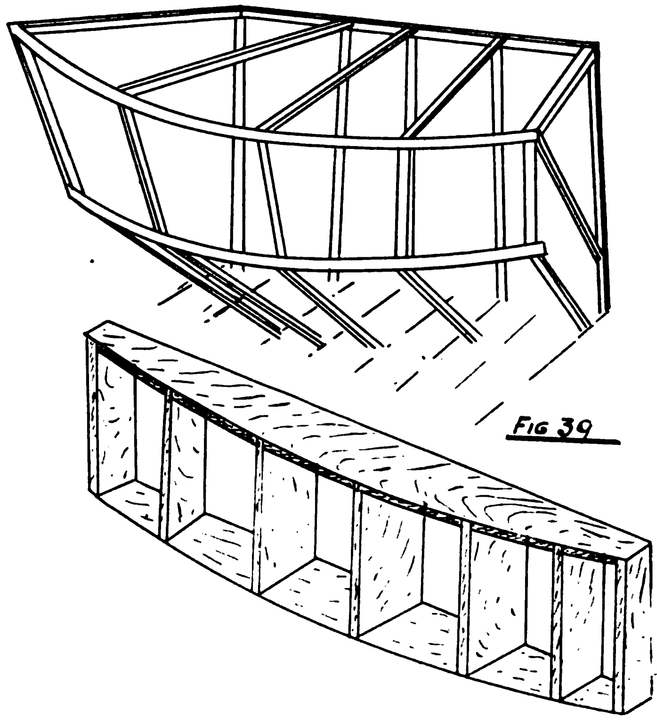


Fig 39

shape of portion of vessel to which they are attached. This work is called "mocking up".

3f. Explaining Mocking Up

An irregular surface which has curvature in two directions cannot be laid out, or developed, by any geometrical rule, therefore, if it is desired to ascertain the exact shape of any portion of shell plating of a vessel having curvature in two directions, it will be necessary to duplicate the particular portion of vessel on mould loft floor and then ascertain the exact shape of plates by bending battens around the built-up form. The work of reproducing the portion of vessel is called *mocking up*.

Mocking up is done in this manner: The mould loftsman makes full-sized models of frames, water-planes and buttocks located at part of vessel that is to be "mocked up" and sets them up in proper position on mould loft floor. These frames are called horses and when they are erected their combined outer surface will form an exact reproduction of portion of vessel that is being mocked up.

On Fig. 39 I show a portion of a mocked-up, elliptical stern and also a mocked-up form of one plate.

I will now explain the *lifting battens* previously referred to.

3g. Lifting Battens

Lifting battens are narrow strips of wood on which are marked accurate height or width measures required by workmen when parts are being got out or erected. Mistakes are more likely to be made if figured measures are entered on a table and table sent to erectors than if the same measures are set off on a batten and batten used as a measuring stick. Therefore all essential setting-up measurements should be marked upon lifting battens.

Here is a list of the principal lifting battens made in mould loft:

(a) Keel and frame lifting battens, on which are marked the distance bottom of keel, inner bottom, and each frame is from base line. Of course these measures can be obtained from the scrieve board but as the measurement points for a number of frames come very close to each other it is safer to make a lifting batten, or a contracted longitudinal diagram on which is marked the actual position of each point relative to base line.

(b) Longitudinal angle bar lifting battens on which are marked the height that root of each longitudinal angle bar is above keel. This batten will be found very useful when setting longitudinals. The measurements for this batten can be obtained from construction details laid out on scrieve board and mould loft floor. On Fig. 40, I show how measurements are taken.

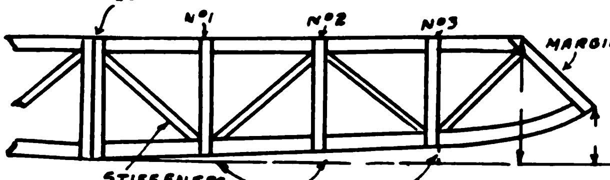


FIG 40

(c) Heights between decks batten. A batten on which position of each deck beam relative to top of inner bottom will be of value when deck beams are being set in their position.

(d) Lengths of pillars. These lengths can be accurately measured from details laid out on mould loft floor and should be marked on battens.

(e) Center of shaft line. A batten on which is marked height shaft center is above base will be of value when checking accuracy of shaft line.

(f) Width of frames. A batten on which is marked the width of each frame at sheer will be very useful to the men assembling and erecting the frames.

There are a number of other battens that can and should be made, but as the above explanation is sufficient to enable you to understand the method of making lifting battens and their use I do not think it necessary to do more than make the following explanation:

Mould loft work is for the purpose of shortening the labor of shaping pieces of material of which a vessel is composed, increasing accuracy, and reducing construction cost. Every hour spent on mould loft work saves many hours of shop and construction labor and the more accurate and detailed the mould loft work is the greater the amount of saving will be. Every essential construction detail and every necessary measurement should be made in mould loft, because it is only by doing this that absolute accuracy can be obtained, and minimum cost of construction insured.

3h. List of Principal Items of Mould Loft Work

Below, I have listed, in proper order, the principal items of mould loft work that should be done when a steel vessel is being laid down.

1. Lines should be laid down full size and faired in manner already explained.
2. Frame outlines, details of double bottom construction, location of decks and longitudinals should be laid out on scrieve board.
3. Bevels should be taken at several points on each frame and properly laid out on bevel boards.
4. A scale model of vessel should be made and all frames, shell plating lines and butt locations marked on it.
5. An expansion plan of shell plating should be laid out and plate edge lines faired on mould loft floor, then lines on mould should be corrected.
6. A skeleton template of keel plate on which is marked butts, seams, and frame positions should be made and on this template there should be marked all rivet holes.

Note.—Whenever possible to do so positions of rivet holes should be indicated on templates by drilling accurate sized holes through template material. When templates are made of pieces that fit against each other the accuracy of rivet holes must be carefully proved before template leaves mould loft. If holes are drilled in templates a great deal of time can be saved in shop when the plater is laying out rivet holes on the pieces of building material.

7. A skeleton template of center line girder, or keelson should be made to correspond with keel plate template.
8. Templates of tank outside knees, intercostals, and vertical lugs should be made.
9. A skeleton template of midship floor mould should be made and on it should be marked details of construction with locations of all rivets for fastening intercostal lugs, frame bars, reverse bars, indicated by means of drilled holes. Limber holes and positions of tank top plate edges and manholes should also be indicated on this template. A tank top plate template is shown on Fig. 41.

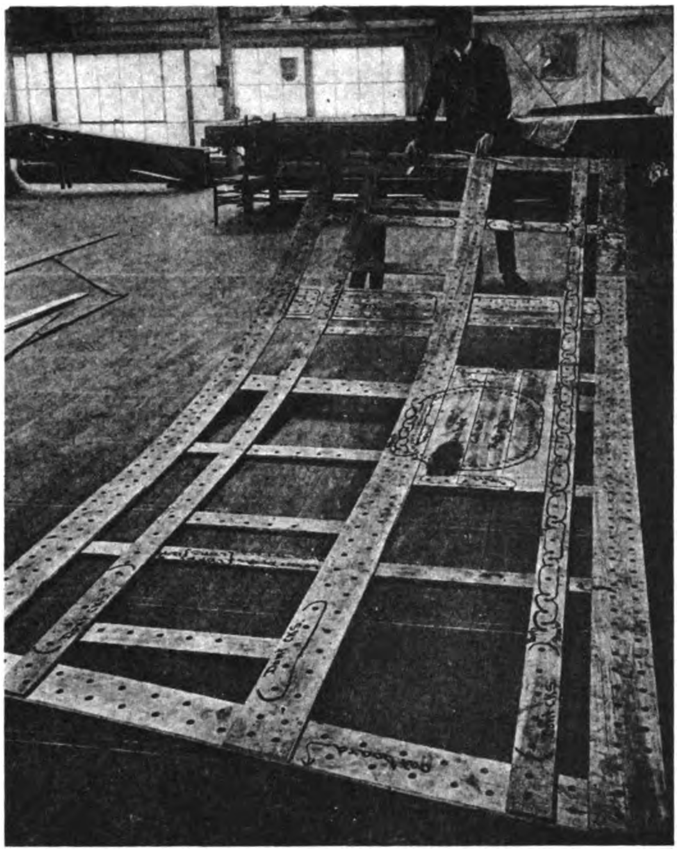


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Fig. 41. A Template Made in Mould Loft

10. A midship section beam mould for each tier of deck beams should be made.

11. Each deck beam outline should be accurately laid out on a separate deck frame scrieve board and on this board there should be marked the exact shapes of deck beam knees.

12. Transverse watertight bulkheads should be laid out on mould loft floor and then a skeleton mould of the largest watertight bulkhead should be made and on it there should be marked full-sized details of stiffeners and other construction details. On this template it is usual to mark outline shape of all other (smaller) watertight bulkheads. Of course all rivet holes should be indicated.

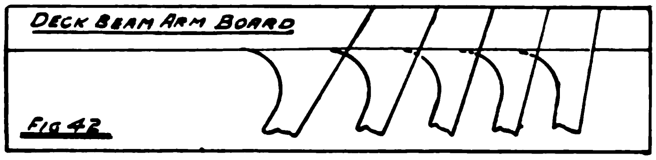
13. If a vessel is fitted with longitudinal watertight bulkheads they should be laid out on mould loft floor and then templates to indicate shape and construction should be made.

14. Stem and stern-post templates should be made and on them there should be marked details and location of scarphs, holes for fastenings, etc. It is also advantageous to lay out on these templates the rivet holes for shell plating.

15. Stringer bar moulds should be prepared. These are pieces of wood the length of bar and breadth of flange and on them the rivet holes are laid out correctly.

16. Stern cant frames should be laid out on mould loft floor and template of each cant made. On these cant templates the bevels should be marked, or a separate set of cant frame bevel boards can be prepared.

17. Stern plating should be laid out on mould loft floor and then all curved shell plates should be "mocked up" and templates made of each plate. These templates must give the exact size and shape of plate as a plane surface and also the exact curvature of plate in all directions.



18. Harpin and sheer ribband shapes must be laid out and templates of their shapes made.

19. Templates of stern tube and struts if struts are used are needed. Measurements for laying out and making these templates are obtained from construction and lines details laid out on mould loft floor.

20. Templates of hawse pipes, on which are given length, diameter and angles of outside and deck flanges, must be made.

21. Templates of davits must be made. These can be full-sized drawings made on pieces of board in manner shown on Fig. 42.

22. Skylights, hatch coamings, booby hatches, watertight doors, and other parts of this nature, must be laid out and templates of each piece of material used in their construction should be made.

23. Templates of deck plating, and of all bracket plates, should be made.

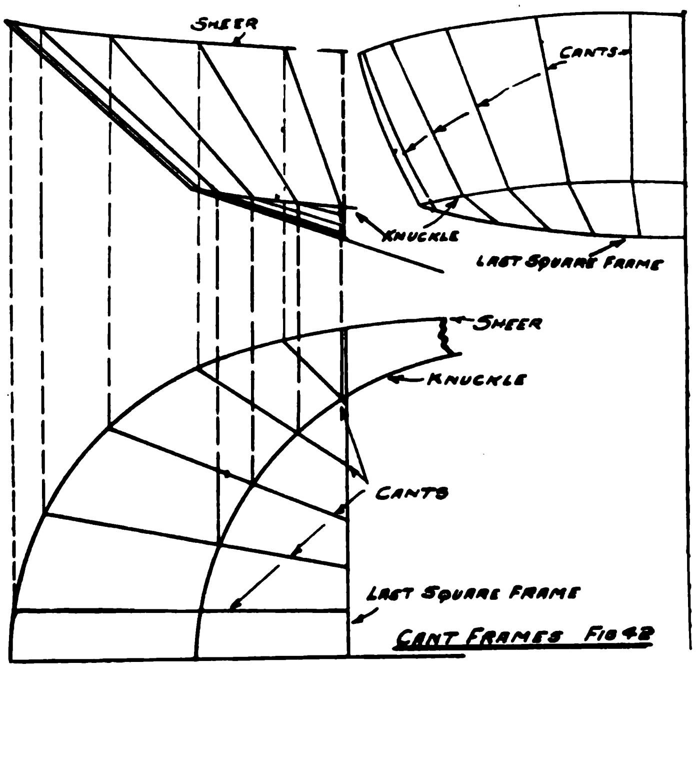
24. Details of deckhouse construction should be laid out and templates of the parts made.

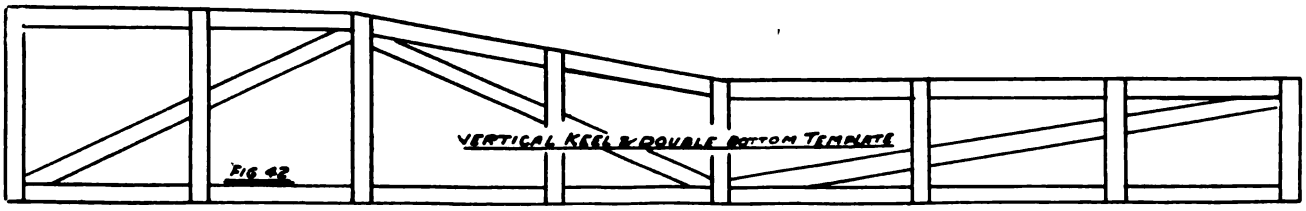
25. Rudder frame details should be laid out and template with full-sized details drawn on it should be made.

26. If bilge keels are to be fitted they should be laid out on mould loft floor and templates of their shape made.

On Fig. 42, I show details of a few parts of templates mentioned in list.

While I have in this and previous parts explained the way to lay out the majority of details mentioned in list, there are a few that require additional explanation; these I will now proceed to explain.



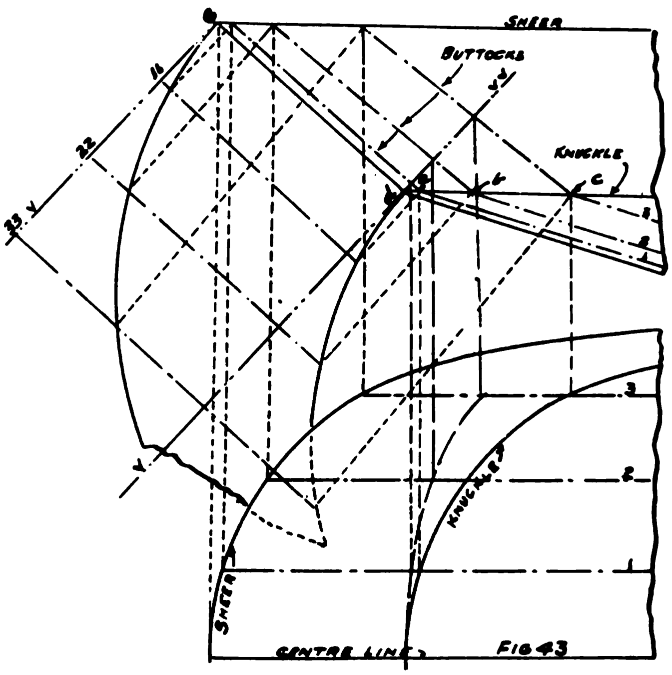


3i. Laying Out, or Expanding the Stern Plating

On Fig. 43 is shown outline shape of an elliptical stern, the upper portion of drawing being profile and the lower portion the plan view as laid out on mould loft floor.

On the drawing the lines 1, 2, 3, indicate location and shape of buttocks.

As the plating of a stern of this shape is usually a cylindrical surface with generators of cylinder parallel to middle line, all that is necessary to obtain true shape



of plating is to unwrap the surface of stern, which can readily be done in this manner:

From the points *a*, *b*, *c*, on profile, which indicate where buttocks 1, 2, 3, touch knuckle, draw perpendiculars to cut knuckle line on plan view, and from the points *d* and *e* draw the lines *dv* and *ev* at right angles to line *de*, which indicates rake of stern plating.

Measure distance along line *dvv* that each buttock line is from point *d* and transfer these measures down to corresponding buttocks on plan view in manner shown by dash lines. A curved line drawn to cut these points on plan view will indicate true length around stern in a plane perpendicular to *de*, and by bending a batten around this curved line and marking on it the points where each buttock crosses the line the true locations of buttock for expansion plan are indicated. By straightening the batten and transferring measurement points to line *ev* the correct distance buttocks are apart on expansion plan is ascertained. Buttock lines 11, 22, 33 are drawn at right angles to line *ev;* and then by transferring points where knuckle and sheer line on profile cross each buttock down to corresponding buttock line on expansion points for true expansion of plating are obtained. Curved lines drawn to cut these points will indicate shape of expanded plate.

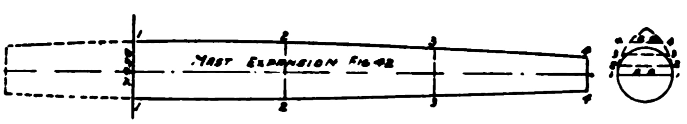
3k. Laying Out Stern Cants (Fig. 42)

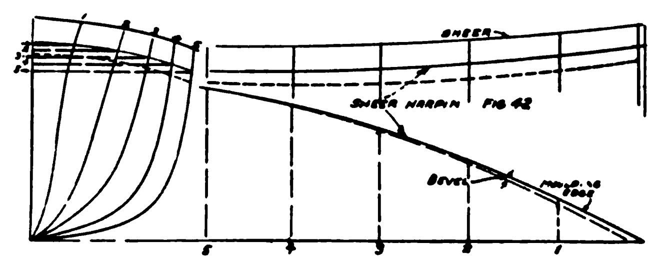
On half-breadth stern plans laid down on mould-loft floor mark the line of direction of cants, marking the first cant at about 18 inches out from center line and locating the other cants at inclinations that will reduce beveling to a minimum. These lines will indicate position of moulding edge of cants. Next transfer half-breadths of cants at sheer, knuckle, and water-lines to body plan, and then transfer points of crossing sheer, knuckle and water-lines up to profile view in manner shown on illustration. By transferring from body plan to profile view height measure and point where each cant meets the last square frame points for upper and lower ends of cants can be obtained.

The beveling edge of cants can be obtained by marking on half-breadth lines parallel with cant moulding lines and a distance away equal to size of flange of cant material. If the points where each of these lines cross sheer, knuckle and water-line is transferred to profile view, points will be obtained for location of beveling edge of cants. On the illustration transferring lines for one cant frame are marked and identified.

3l. Laying Out Sheer Harpin (Fig. 42)

A sheer harpin is an angle which runs along sheer of vessel at a distance of about 6 inches below the deck. On illustration I show a portion of a sheer harpin marked on profile, half-breadth, and body plans, and as each line is identified by name detailed explanation of method of laying out is not necessary. The moulding edge line is first marked on profile view, then transferred to body plan, and by measuring on body plan from center line out to where harpin line crosses each frame outline, points for laying out half-breadth view of harpin can be obtained. The location of beveling edge is next marked on profile view a distance below beveling edge equal to flange measurement of angle that is to be used. This





line is transferred to body plan and then by lifting bevels at each frame and transferring to half-breadth plan spots for beveling edge can be obtained.

3m. To Lay Out a Mast Expansion (Fig. 42)

A straight line is drawn to indicate length of mast from deck to top. Diameter at deck is generally given on plan. Head is generally ⅝ the deck diameter and heel ¾ deck diameter. Draw a circle having diameter equal to diameter at deck, then from points *A, B* describe arcs cutting in *X*.

At the point on arcs where distance between them is equal to ⅝ of the deck diameter draw the line *CD*.

Next divide the space between *AB* and *CD* into any selected number of equal parts (say three) and draw parallel lines from arc to arc. If the mast length from deck to top is divided into the same number of parts that arc is and each parallel line on arc is measured and half its measure transferred each side of center mast line to corresponding line marked across it, a series of points will be obtained each side of center line of mast, and curved lines drawn to cut these points will indicate true longitudinal curve for mast diameter from deck to top. Portion of mast below deck is laid out in a similar manner.

3n. Laying Down a Vessel When Mould Loft Floor is Shorter Than Length of Vessel

In cases when this occurs it is necessary to divide the vessel's length into two or three parts and to lay down each part separately, care being taken to include in each part a portion of the other part, or parts, and thus insure that there will not be any "flat" or unfair lines at points of division. I have explained this in another paragraph.

In cases when after dividing vessel into parts as explained above, mould loft floor is still too short to properly lay down one of the parts, it will be necessary to resort to *contraction,* or reduction of interval between ordinates, for *the middle body portion of vessel.*

To explain this I will assume that it is necessary to lay down the lines of a 165-foot steel vessel upon a mould loft floor that is only 60 feet in length. Fig. 46 shows lines drawing of such a vessel.

Measurements taken from lines drawing indicates that the interval measure between ordinates is 9.9 feet, and that length of vessel over all is 165.5 feet.

If, therefore, the longitudinal length is divided at No. 7 and at No. 12 ordinates, there will be three parts and the bow and stern portions of vessel can be laid down without contracting interval between their ordinates, the middle portion with necessary amount of overlap to insure the lines being fair can also be laid down, *providing interval measure between ordinates is reduced one-half* (from 9.9 feet to 4.95 feet).

Meaning of Overlap

To explain this I have drawn illustration No. 45, which shows a longitudinal water plane of a vessel.

If a batten is bent to follow the curved outline of this plane from bow to stern the whole of line can be accurately marked out at one time, but if owing to mould loft floor being too short it becomes necessary to divide this plane at the point -a- and lay line out in two portions, then fairness of curve at the point of junction -a- cannot be obtained without including at least two ordinates of bow portion with stern when that portion is being laid down, and two ordinates of stern portion with bow when that portion is being laid down. Thus bow portion is laid down as if it extended to -c-.

The portion from -b- to -c- is called the overlap and it must always be of sufficient length to insure that there will not appear any flat line where junction is (-a-).

In practice it will be found necessary to make overlap extend for at least a distance of two ordinate intervals and to locate the points of division at positions where there is a minimum of change in shapes of water-lines.

Laying Down the Contracted Middle Body Portion

I will assume that the middle portion of vessel has to be contracted to one-half the full interval between ordinates, or from 9.9 feet to 4.95 feet. The contraction is made by spacing ordinates one-half the correct (full) interval apart, and, of course, the spacing of frames must also be contracted in a similar manner.

No contraction is made vertically with depth, spacing of water-lines or sheer heights. Perhaps it will be best for me to explain the whole procedure of laying down the vessel's lines in three separate portions.

First, the fore body profile, half-breadth water-lines and cross-section outlines from No. 1 to No. 7 ordinates is marked on mould loft floor and lines faired in manner you would lay down and fair the whole of a vessel's lines. Next, portion from stern to No. 12 ordinate is

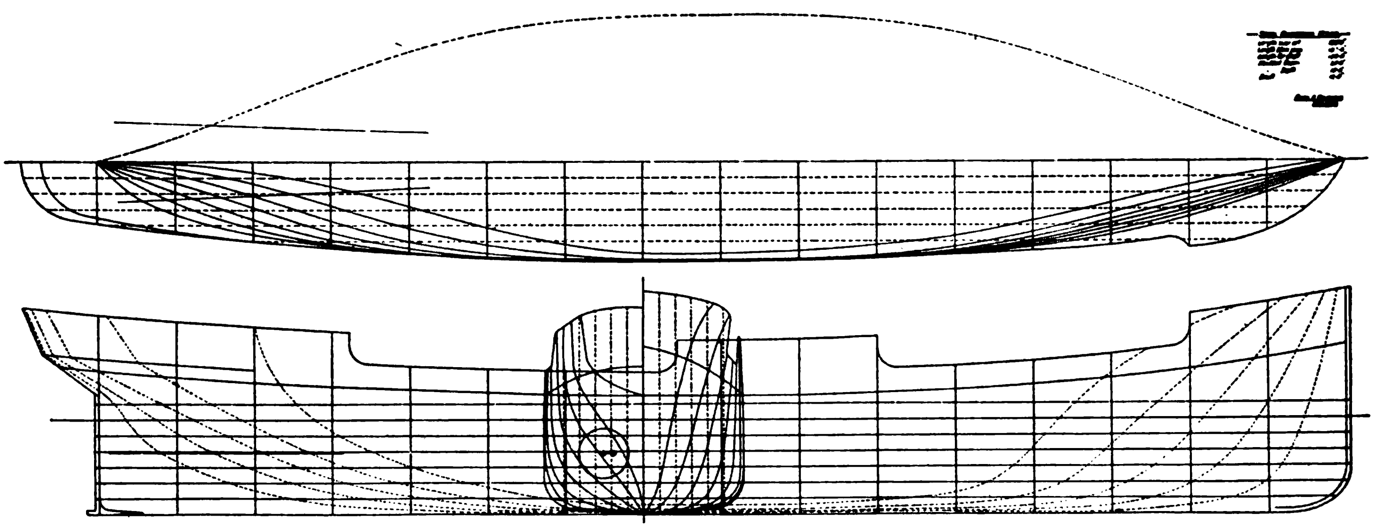


Fig. 46. Lines of 166-Foot Cargo Boat, Designed by Royal Polhamus

laid down and faired in a similar manner. You must, of course, remember that the ordinates for these portions are spaced at their full measured distances (9.9 feet) apart, because you cannot accurately lay down the fore and after body lines of a vessel if intervals between ordinates are contracted, the reason for this being that there is too much round, or change, in shape of fore-and-aft lines at these portions.

After the fore and after portions are faired the profile and half-breadth water-line plan ordinates for middle portion are marked on floor at *one-half their interval distance apart* and then the correct measurement points are marked on these ordinates, and the lines marked and faired in usual manner. Of course, as height measures for profile and width measures for half-breadth water-lines are not changed the actual shape of each curved line on these views will not be changed except longitudinally, and therefore measurements can be taken from profile and half-breadth water-lines for use when laying out and fairing cross-section shapes, and when fairing the lines.

Each portion of vessel is laid out and faired as a separate unit, except the cross-section and frames outlines, which are always laid out on one scrive board in exactly the manner they would be laid down if all the fore-and-aft lines of vessel were being laid down at one time.

Some care must be taken with fairing lines at the junction of middle body with bow and stern portions, but if at least two intervals (three ordinates) are used it will be possible to entirely eliminate the tendency to flatness that has to be guarded against when lines of a vessel are laid out in parts and parts joined.

30. Fairing the Shell Plating Edges

I have already told you the lines that edges of shell plates follow are first marked on a scale model, and then transferred to a full-sized expansion plan of plating laid down on mould loft floor. This method will insure that all the plating lines are fair, but it may not insure that all plate edges are clear of longitudinals and other structural details likely to interfere with riveting or with the securing of outer appendages, such as bilge keels, bosses of shaft brackets, etc.

It is therefore advisable that after plating lines are faired on expansion plan they be transferred to frame outline plan laid down on scrive board and their accuracy again proved by observing if all the plate edge lines are well clear of inner longitudinals and outer appendages. Of course positions of both inner longitudinals and outer appendages must be marked on scrive board before this proof can be made.

Here are a few details that should be kept in mind:

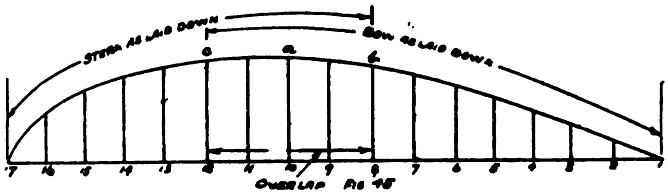
(a) When laying out plate edge lines make sure that there is a minumum of sag, or curvature, of edges, because the greater the curvature is the larger the amount of waste material there will be.

(b) See that plating edges do not cross bilge keels or longitudinals, and that boss plate fits on only one plate. Boss plates serve to reinforce shell plating at locations where palms, or bosses, of struts or shaft supports are fastened to a hull and best results are obtained when these reinforcing plates fit between upper and lower edge of a strake of plating.

3p. Suggestions

Keel Plate Mould is generally a skeleton template made out of thin material and on it is marked the butts, the seams, the frame locations. In addition to this all holes for fastenings are marked in their proper positions by drilling correct diameter holes through the template material. Drilling the fastening holes insures that all holes in keel plate will be in their exact location, because when template is laid on the steel the shipfitter can readily and accurately transfer every fastening hole. At the same time that keel template is being made there should also be made a template of *center girder.*

Stem Mould is made to indicate exact shape and size of stem and on it is marked the locations of all fastening holes for shell plating, etc., and also positions of decks, plate edges and frames. It is usual to make this template of wood having same dimensions that stem will have. The stem template is used as a guide for shaping stem, and also for locating positions of fastenings.



Stern Post Template is a companion template to the stem, but as the stern casting is generally shaped to permit shaft to pass through (this is in single screw vessels) it is necessary to indicate on template, by means of a full-sized drawing, the exact shape of stern casting at point where it is enlarged for shaft. In some yards in place of making a wood template a full-sized drawing of stern casting or forging is laid out and this drawing is sent to patternmaker or to the department that will prepare the stern frame.

Rudder Frame Templăte is made to indicate shape of rudder frame, or rudder frame is laid out full size and detail drawing sent to the department that will make rudder frame.

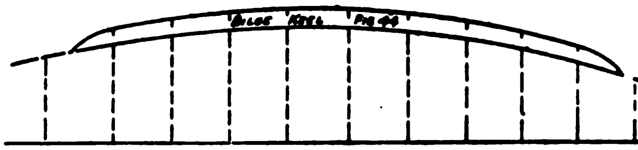
It is very essential when laying out a rudder frame to make sure that rudder can be readily withdrawn from stern post when vessel is in dry dock.

Bilge Keel Template.—Bilge keels are now fitted to a large number of vessels for the purpose of reducing rolling and thus steadying vessel in a sea. They are fitted in the neighborhood of bilges and consist of projecting plates secured to the hull by T-bars, or angles, that extend from end to end of bilge keels.

The designer usually marks their location on plans so all that the mould loftsman has to do is to accurately locate bilge keel and make sure that all fastenings that secure them to hull are well clear of obstructions, and also that the bilge keels do not have to cross a plate edge.

When a bilge keel is composed of a plate it can be readily laid out in this manner:

First, locate position on body plan and mark a diagonal line to cut points marked on frame outlines to indi-



cate where bilge keel crosses frame. This diagonal line will be a fair one if the points are correct. After points are laid out and line faired on body plan the curve to indicate inner and outer edge of bilge keel should be laid out on longitudinal plan. Points for laying out this curve can be obtained from body plan and diagonal fair line that you have already faired.

When the curved line is marked the forward and after points of keel should be rounded in the manner shown on Fig. 44, which is an outline of bilge keel curve.

Chapter IV

Laying Down Sections of Solids

On the accompanying illustration sheet (Plate I), I show a number of regular solids and below I explain in detail rules for laying out the sections named, all of which are taken at varying angles to base or side. I suggest that you carefully study the illustrations and actually learn how each section is obtained. Knowledge of this kind will prove invaluable when problems arise that call for the laying out of sections of vessels taken at some acute or obtuse angle.

Plate I. Fig. 1.—*To draw the sections of a cone made by a line cutting both its sides.*

Let A D B be the vertical projection of the cone, A C B the horizontal projection of half its base, and E F the line of section. From the points E and F, let fall on A B the perpendiculars E G, F H; and on G H describe the semicircle G 4 H, which is the horizontal projection of half of the section. To find the vertical section—Divide the semicircle G 4 H into any number of equal parts, 1 2 3 4, etc.; and through these divisions draw lines 1 5 K, 2 6 *l*, 3 7 *m*, 4 8 *n*, perpendicular to the line A B, and meeting the section line E F in the points *k l m*, etc. Through *k l m*, etc., draw *k t*, *l u*, *m v*, *n w*, perpendicular to E F, and make them respectively equal to the corresponding ordinates, 5 1, 6 2, 7 3, etc., of the semicircle G 4 H, and points will be obtained through which the ellipse E *w* F may be traced. It is obvious that, practically, it is necessary only to find the minor axis of the ellipse, the major axis E F being given.

If through the points E *k l m n*, etc., lines be drawn parallel to A B, etc., meeting the side of the cone, as in *o p q r s*, and from these perpendiculars to be let fall on A B, in *x y z a b*, then arcs described from the center of the base of the cone 1, with the radii 1 G, 1 1, 1 2, will meet these perpendiculars. This is applied in the two following figures, to finding the projections of other sections of the cone.

Figs. 2 and 3.—*To draw the sections of a cone made by a line parallel to one of its sides.*

Let A D B be the vertical projection of a right cone, and A C B half the plan of its base; and let E F be the line of section. In E F take any number of points, E *a b c d e* F, and through them draw lines E H, *a* 6 1, *b* 7 2, etc., perpendicular to A B. Through *a b c d e*, draw also lines parallel to A B, meeting the side of the cone in *f g h k l*; from these let fall perpendiculars on A B, meeting it in *m n o p q*. From the center of the base 1, with the radii 1 *m*, 1 *n*, 1 *o*, etc., describe arcs cutting the perpendiculars let fall from the section line in the points 1 2 3 4 5; and through the points of intersection trace the line H 1 2 3 4 5 G, which is the horizontal projection of the section. To find the vertical section—On E *a b c d e*, raise perpendiculars to E F, and make them respectively equal to the ordinates in the horizontal projection, as E *r* equal to E H, *a s* equal to 6 1, etc., and the points *r s t u v w* in the curve will be obtained.

Fig. 4, Nos. 1—4.—*To draw the section of a cuneoid made by a line cutting both its sides.*

A cuneoid is a solid ending in a straight line, in which, if any point be taken, a perpendicular from that point may be made to coincide with the surface. The end of the cuneoid may be of any form; but in architecture it is usually semicircular or semi-elliptical, and parallel to the straight line forming the other end.

Let A C B (No. 1) be the vertical projection of the cuneoid, and A 5 B the plan of its base, and A B (No. 4) the length of the arris at C, and let D E be the line of section.

Divide the semicircle of the base into any number of parts 1 2 3 4 5, and through them draw perpendiculars to A B, cutting it in *l m n o p*, and join C *l*, C *m*, C *n*, etc., by lines cutting the section line 6 7 8 9, etc. From these points draw lines perpendicular to D E, and make them equal to the corresponding ordinates of the semicircle, either by transferring the lengths by the compasses, or by proceeding as shown in the figure.

The section on the line D K is shown in No. 2, in which A B equals D K; and the divisions *e f g h k* in D K, etc., are transferred to the corresponding points on A B; and the ordinates *e l*, *f m*, *g n*, etc., are made equal to the corresponding ordinates *l* 1, *m* 2, *n* 3, of the semicircle of the base. In like manner, the section on the line G H, shown at No. 3, is drawn.

Fig. 5.—*To describe a cylindric section through a line given in position.*

Let A B G F be a section of a right cylinder passing through its axis; and let C D be the line of the required section. On A B describe a semicircle, and in the arc take any number of points, 1 2 3 4 5, from which draw lines perpendicular to A B, cutting it in *o p q r s*, and produced to meet the line of section C D, in the points 6 7 8 9 10, etc. From these points draw the lines 6 *t*, 7 *u*, 8 *v*, 9 *w*, 10 *x*, etc., perpendicular to C D, and make these ordinates respectively equal to the ordinates *o* 1, *p* 2, *q* 3, *r* 4, *s* 5; then through the points C *t u v w*, etc., draw the curve, which will be the section required. The heights of the ordinates may be simply transferred by the compass, or thus: Produce the line of section C D to E, to meet the diameter A B produced: draw E *n* perpendicular to E D, and E *n* perpendicular to E B. From the points in the arc 1 2 3 4 5, draw lines 1 *h*, 2 *k*, 3 *l*, 4 *m*, 5 *n*, meeting the line E *n*, then with the center E and radii E *h*, E *k*, E *l*, E *m*, E *n*, describe the arcs *h h*, *k k*, etc., and from the points *h k l m n*, where these arcs meet the line E *n*, draw the lines *n x*, *m a*, *l b*, *k c*, *h d*, cutting the ordinates 6 7 8 9 10, etc., in the points *t u v w x a b c d*, through which draw the curve of the required section.

Fig. 6.—*To describe the cylindric section made by a curved line cutting the cylinder.*

Let A B D E be the section of the cylinder, and C D the line of the section required. On A B describe a semicircle, and divide it into any number of parts as before. From the points of division draw ordinates 1 *h*, 2 *k*, 3 *l*, 4 *m*, etc., and produce them to meet the line of the section in *o p q r s t u v w*. Bend a rule or slip of paper to the line C D, and prick off on it the points C *o p q*, etc.; then draw any straight line F G, and unbending the rule, transfer the points C *o p q*, etc., to F *a b c d*, etc. Draw the ordinates *a* 1, *b* 2, *c* 3, and make them respectively equal to the ordinates *h* 1, *k* 2, *l* 3, etc., and through the points found trace the curve.

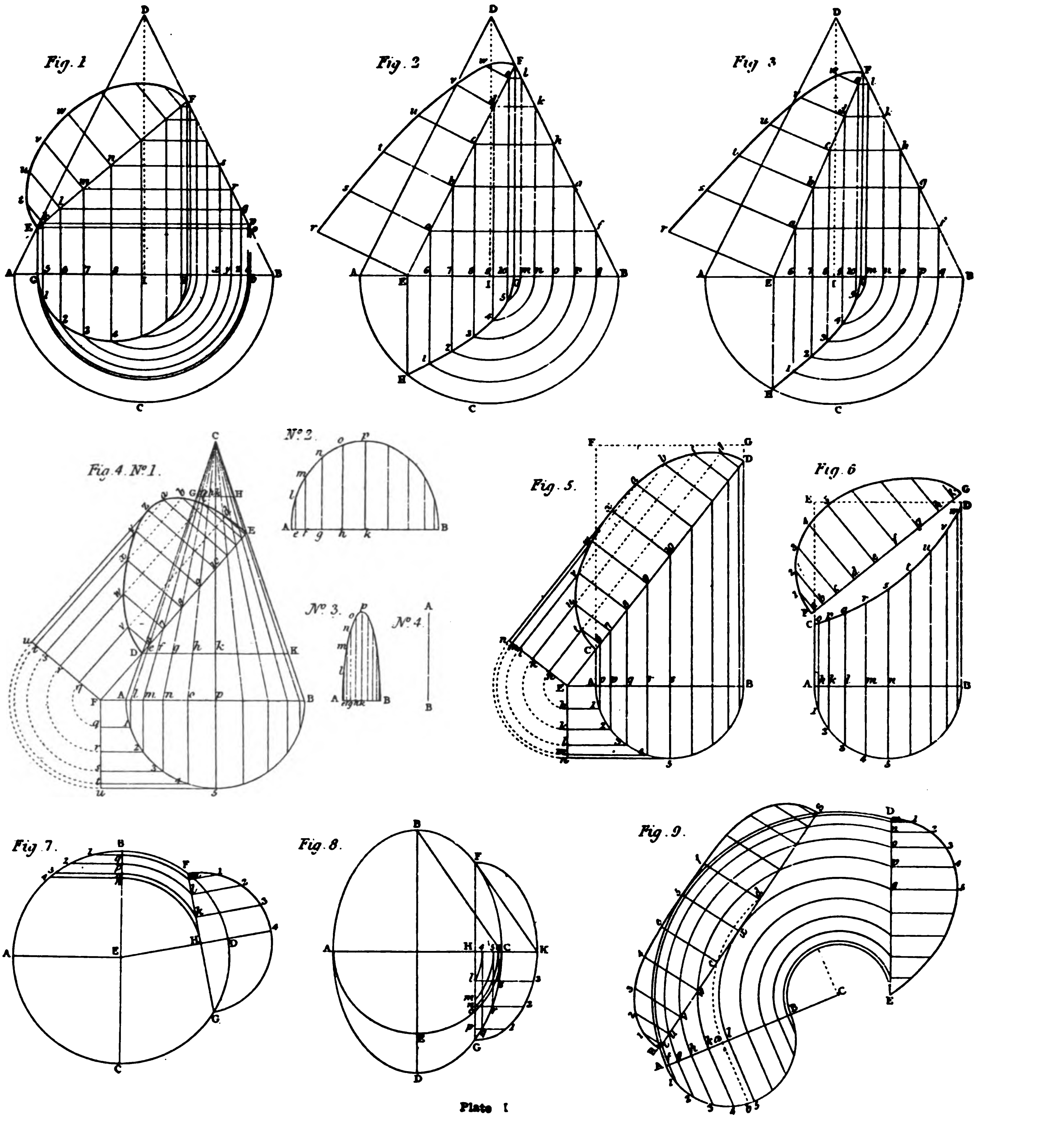


Plate I

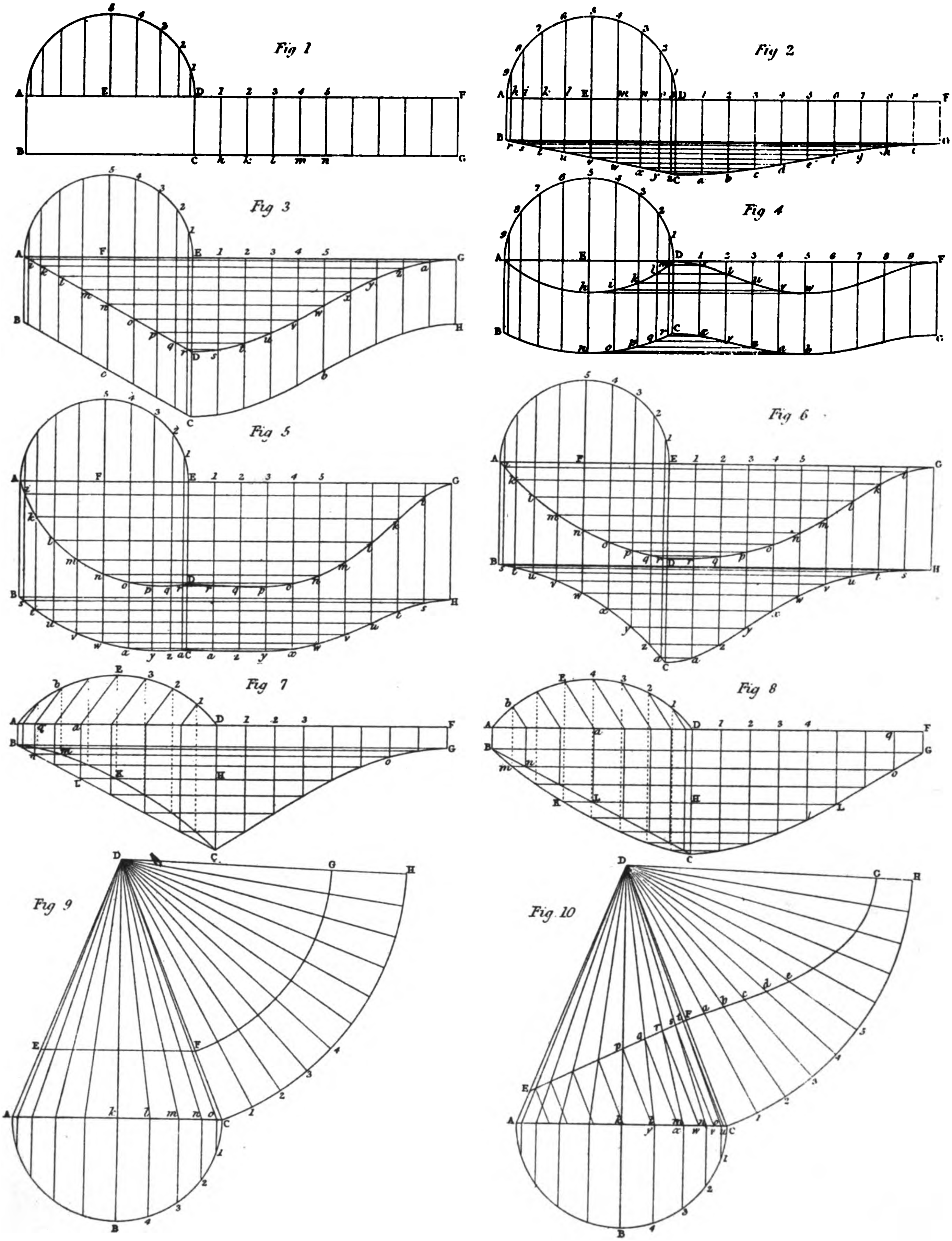


Plate II

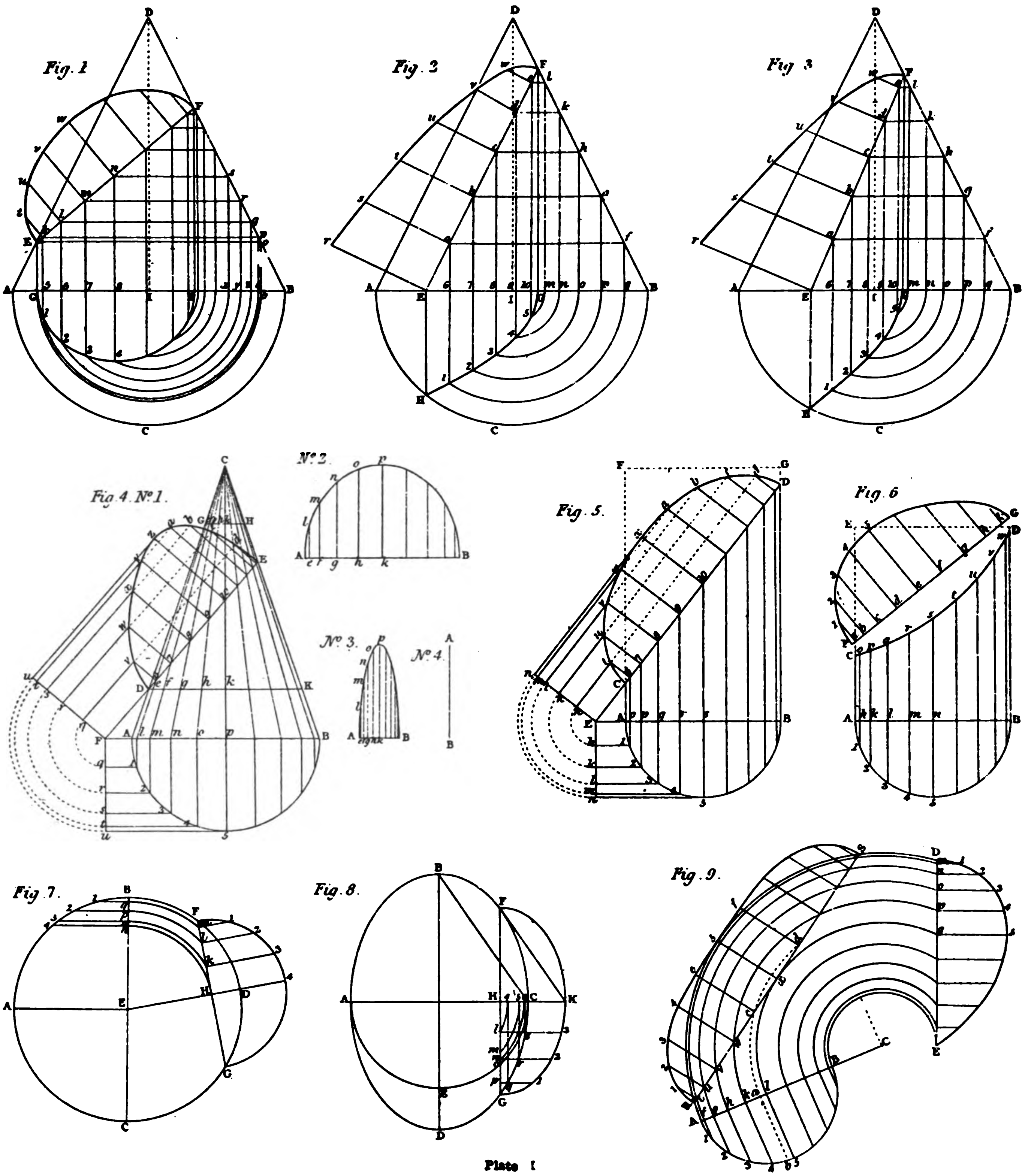


Plate I

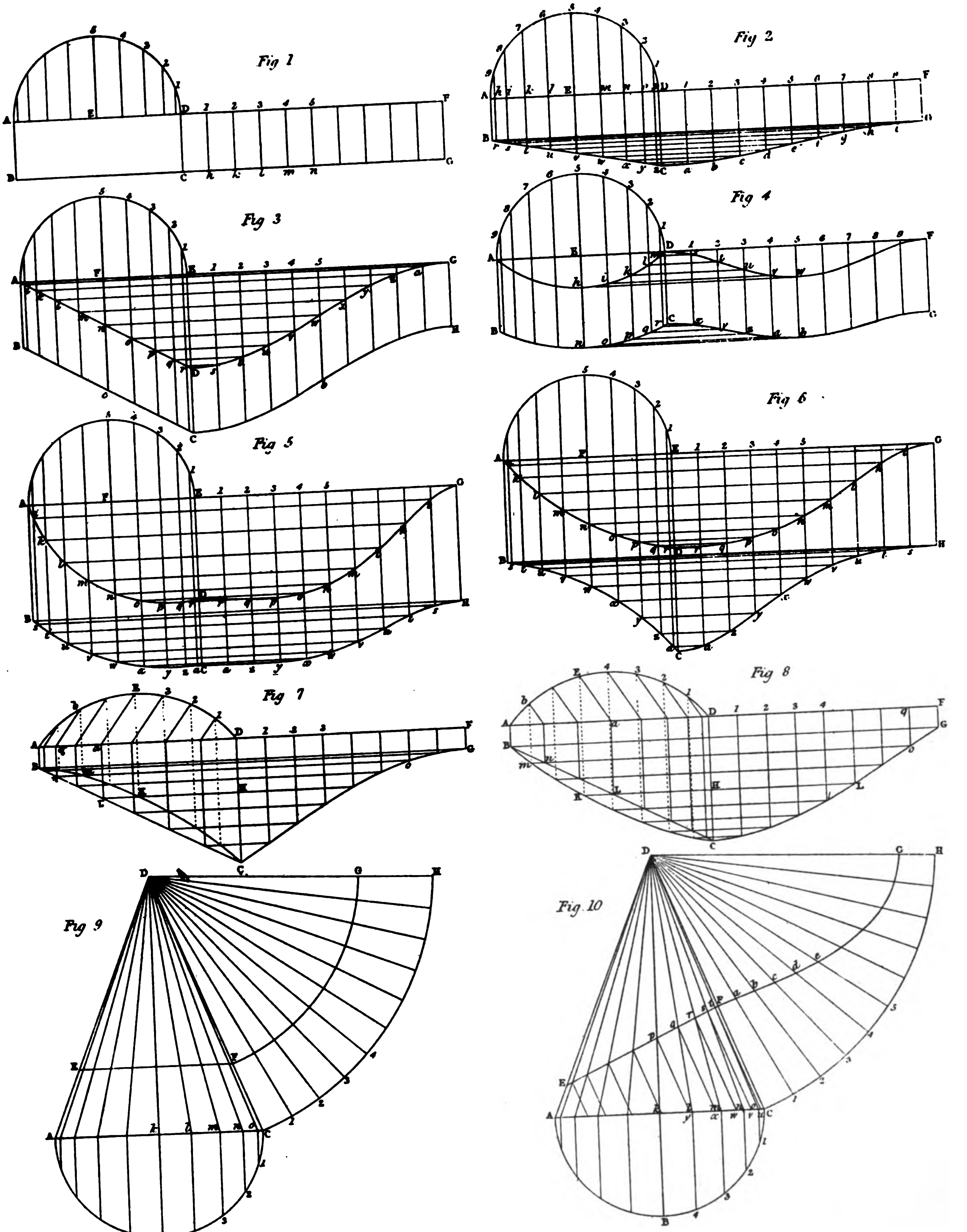


Plate II

Fig. 7.—*To describe the section of a sphere.*

Let A B D C be the great circle of a sphere, and F G the line of the section required. Then, since, as we have seen, all the sections of a globe or sphere are circles, on F G describe a semicircle F 4 G, which will be the section required.

Or, in F G take any number of points in *m l k* H, and from the center of the great circle E, describe the arcs H *n*, *k o*, *l p*, *m q*, and draw the ordinates H 4, *k* 3, *l* 2, *m* 1, and *n* 4, *o* 3, *p* 2, *q* 1; then make the ordinates on F G equal to those on B C, and the points so obtained will give the section required.

Fig. 8.—*To describe the section of an ellipsoid, when a section through the fixed axis, and the position of the line of the required section, are given.*

Let A B C D be the section through the fixed axis of the ellipsoid, and F G the position of the line of the required section. Through the center of the ellipsoid, draw B D parallel to F G; bisect F G in H, and draw A C perpendicular to F G; join B C, and from F draw F K, parallel to B C, and cutting A C produced in K; then will H K be the height of the semi-ellipse forming the section on F G.

Or, the section may be found by the method of ordinates, thus: As the section of the ellipsoid on the line A C is a circle, from the point of intersection of B D and A C describe a semicircle A E C. Then on H G, the line of section, take any number of points *l m n o p*, and from them raise perpendiculars cutting the ellipse in *q r s*. From *q r s* draw lines perpendicular to A C, cutting it in the points 4 5 6; and again, from the intersection of B D and A C as a center, draw the arcs 4 *l*, 5 *m*, 6 *n*, C *o*, cutting H G in *l m n o;* then H *o*, set off on the perpendicular from H to K, is the height of the section; and the heights H *n*, H *m*, H *l*, set off on the perpendiculars from *l* to 3, *n* to 2, and *p* to 1, give the heights of the ordinates.

Fig. 9.—*To find the section of a cylindrical ring perpendicular to the plane passing through the axis of the ring, the line of section being given.*

Let A B E D be the section through the axis of the ring, A B be a straight line passing through the concentric circles to the center C, and D E be the line of section. On A B describe a semicircle; take in its circumference any points as 1 2 3 4 5, etc., and draw the ordinates 1 *f*, 2 *g*, 3 *h*, 4 *k*, etc. Through the points *f g h k l*, etc., where the ordinates meet the line A B, and from the center C, draw concentric circles, cutting the section line in *m n o p q*, etc. Through these points draw the lines *m* 1, *n* 2, *o* 3, etc., perpendicular to the section line, and transfer to them the heights of the ordinates of the semicircle *f* 1, *g* 2, etc.; then through the points 1 2 3 4, draw the curve D 5 E, which is the section required.

Again, let R S be the line of the required section; then from the points *t u v w c x d*, etc., where the concentric circles cut this line, draw the lines *t* 1, *u* 2, *v* 3, etc., perpendicular to R S, and transfer to them the corresponding ordinates of the semicircle; and through the points 1 2 3 4 *e* 5 *f*, draw the curve R *e f* S, which is the section required.

To find the covering of a right cylinder.

PLATE II.—Let A B C D (Fig. 1) be the seat or generating section. On A D describe the semicircle A 5 D, representing the vertical section of half the cylinder, and divide its circumference into any number of equal parts, 1 2 3 4 5, etc., and transfer those divisions to the lines A D and B C produced; then the parallelogram D C, G F will be the covering required.

To find the edge of the covering when it is oblique in regard to the sides of the cylinder.

Let A B C D (Fig. 2) be the seat of the generating section, the edge B C being oblique to the sides A B, D C: draw the semicircle A 5 D, and divide it into any number of parts, as before; and through the divisions draw lines at right angles to A D, producing them to meet B C in *r s t u v*, etc. Produce A D, and transfer to it the divisions of the circumference, 1 2 3 4 5 6, etc.; and through them draw indefinitely the lines 1 *a*, 2 *b*, 3 *c*, perpendicular to D F: to these lines transfer the lengths of the corresponding lines intercepted between A D and B C, that is, to 1 *a* transfer the length *p z*, to 2 *b* transfer *o y*, and so on, by drawing the lines *z a*, *y b*, *x c*, etc., parallel to A F, the intersections; then shall D F C G be the development of the covering of A B C D.

To find the covering of a semi-cylindric surface contained between two parallel planes perpendicular to the generating section.

Let A B C D (Fig. 3) be the seat of the generating section: from A draw A G perpendicular to A B, and produce C D to meet it in E: on A E describe the semicircle, and transfer its perimeter to E G, by dividing it into equal parts, and setting off corresponding divisions on E G. Through the divisions of the semicircle draw lines at right angles to A E, producing them to meet the lines A D and B C, in *i k l m*, etc. Through the divisions on E G draw lines perpendicular to it; then through the intersections of the ordinates of the semicircle, with the line A D, draw the lines *i a*, *k z*, *l y*, etc., parallel to A G, and where these intersect the perpendiculars from E G, in the points *a*, *z*, *y*, *x*, *w*, *v*, *u*, etc., trace a curved line G D, and draw parallel to it the curved line H C; then will D C, H G, be the development of the covering required.

To find the covering of a semi-cylindric surface bounded by two curved lines.

Figs. 4, 5, 6.—The construction to obtain the developments of these coverings is precisely similar to that described in Fig. 3, as will be evident on inspection.

To form the edge of a cylindric surface terminated by a curved line, so that when the envelope is applied to the surface its edge may coincide with a plane passing through three given points.

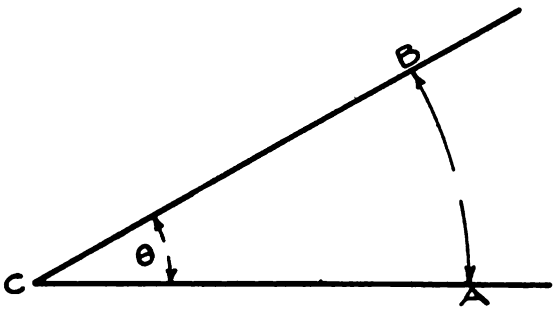
Let A E D (Figs. 7 and 8), be the base of the solid. Draw A B and D C perpendicular to A D, and make A B equal to the height of the point whose seat is A, and D C equal to the height of the point whose seat is D. On D C make H equal to the height of the point whose seat is E: join B C. Draw H L (Fig. 7) parallel to A D and H K (Fig. 8), cutting B C in L. Draw L *a* parallel to D C, cutting A D in *a*: join *a* E. Divide the arc of the base into any number of equal parts in 1, 2, 3, 4, etc., and extend them on A D produced to F. Then to find any point in the envelope—suppose that which corresponds to *b* on the seat. Draw *b q* parallel to *a* E, cutting A D at *q;* draw also *q n* parallel to D C, cutting B C in *n*. Make *q' o* equal to *q n*, and *o* is a point in the line required. Proceed in the same manner with other points until the line C *o* G (Fig. 7) and C L *o* G (Fig. 8) is obtained.

To find the covering of the frustum of a cone, the section being made by a plane perpendicular to the axis.

Let A C E F (Fig. 9) be the generating section of the frustum. On A C describe the semicircle A B C, and produce the sides A E and C F to D. From the center D, with the radius D C, describe the arc C H; and from the same center, with the radius D F, describe the arc F G: divide the semicircle into any number of equal parts, and run the same divisions along the arc C H; draw the ordinates to the semicircle through the points of division, at right angles to, and meeting A C; and from the point *o n m*, etc., where these ordinates cut the line A B, draw lines to the point D; and from the last division in the arc C H, draw also a line to the point D; then shall C H G F be half the development of the covering of the frustum A C F E.

To find the covering of the frustum of a cone, the section being made by a plane not perpendicular to the axis.

Let A C F E (Fig. 10) be the frustum. Proceed as in the last problem to find the development of the covering of the semicone: then, to determine the edge of the covering on the line E F. From the points *p q r s t*, etc., draw lines perpendicular to E F, cutting A C in *y x w v u*; and the length *u t* transferred from 1 to *a*, *v s* transferred from 2 to *b*, and so on, will give *a b c d e* G, points in the edge of the covering.



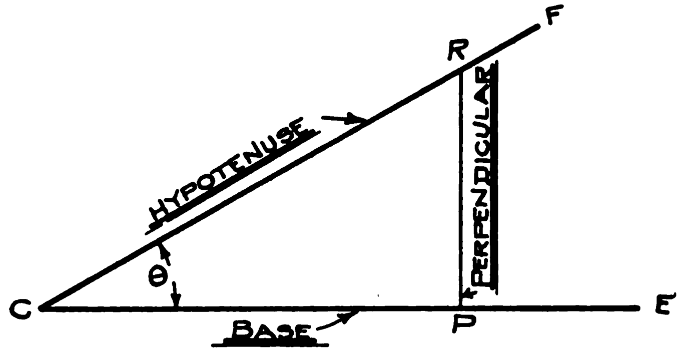


TABLE OF NATURAL SINES AND TANGENTS.

ANGLE	SINE θ	TANGENT	ANGLE	SINE θ	TANGENT	ANGLE	SINE θ	TANGENT
DEG°	SIN θ	TAN θ	DEG°	SIN θ	TAN θ	DEG°	SIN θ	TAN θ
1	.0175	.0175	16	.2756	.2867	31	.5150	.6009
2	.0349	.0349	17	.2924	.3057	32	.5299	.6249
3	.0523	.0524	18	.3090	.3249	33	.5446	.6494
4	.0698	.0699	19	.3256	.3443	34	.5592	.6745
5	.0872	.0875	20	.3420	.3640	35	.5736	.7002
6	.1045	.1051	21	.3584	.3839	36	.5878	.7265
7	.1219	.1228	22	.3746	.4040	37	.6018	.7536
8	.1392	.1405	23	.3907	.4245	38	.6157	.7813
9	.1564	.1584	24	.4067	.4452	39	.6293	.8098
10	.1736	.1763	25	.4226	.4663	40	.6428	.8391
11	.1908	.1944	26	.4384	.4877	41	.6561	.8693
12	.2079	.2126	27	.4540	.5095	42	.6691	.9004
13	.2250	.2309	28	.4695	.5317	43	.6820	.9325
14	.2419	.2493	29	.4848	.5543	44	.6947	.9657
15	.2588	.2679	30	.5000	.5774	45	.7071	1.000

Rules Relative to the Circle, etc.

To Find Circumference—

Multiply diameter by 3.1416.
Or divide " " 0.3183.

To Find Diameter—

Multiply circumference by 0.3183.
Or divide " " 3.1416.

To Find Radius—

Multiply circumference by 0.15915.
Or divide " " 6.28318.

To Find Side of an Inscribed Square—

Multiply diameter by 0.7071.
Or multiply circumference by 0.2251.
" divide " " 4.4428.

To Find Side of an Equal Square—

Multiply diameter by 0.8862.
Or divide " " 1.1284.
" multiply circumference by 0.2821.
" divide " " 3.545.

SQUARE—

A side multiplied by 1.4142 equals diameter of its circumscribing circle.

A side multiplied by 4.443 equals circumference of its circumscribing circle.

A side multiplied by 1.128 equals diameter of an equal circle.

A side multiplied by 3.547 equals circumference of an equal circle.

Square inches multiplied by 1.273 equal circle inches of an equal circle.

To Find the Area of a Circle—

Multiply circumference by one-quarter of the diameter.
Or " the square of diameter by 0.7854.
" " " " circumference " .07958.
" " " " ½ diameter " 3.1416.

To Find the Surface of a Sphere or Globe—

Multiply the diameter by the circumference.
Or " " square of diameter by 3.1416.
" " four times the square of radius " 3.1416.

To Find the Weight of Brass and Copper Sheets, Rods and Bars—

Ascertain the number of cubic inches in piece and multiply same by weight per cubic inch.

Brass, 0.2972.

Copper, 0.3212.

Or multiply the length by the breadth (in feet) and product by weight in pounds per square foot.

USEFUL TABLES

FRACTIONS OF AN INCH IN DECIMALS

Fraction of an Inch	Decimal of an Inch	Fraction of an Inch	Decimal of an Inch	Fraction of an Inch	Decimal of an Inch	Fraction of an Inch	Decimal of an Inch
1/64	.01562	17/64	.26562	33/64	.51562	49/64	.76562
1/32	.03125	9/32	.28125	17/32	.53125	25/32	.78125
3/64	.04687	19/64	.29687	35/64	.54687	51/64	.79687
1/16	.06250	5/16	.31250	9/16	.56250	13/16	.81250
5/64	.07812	21/64	.32812	37/64	.57812	53/64	.82812
3/32	.09375	11/32	.34375	19/32	.59375	27/32	.84375
7/64	.10937	23/64	.35937	39/64	.60937	55/64	.85937
1/8	.12500	3/8	.37500	5/8	.62500	7/8	.87500
9/64	.14062	25/64	.39062	41/64	.64062	57/64	.89062
5/32	.15625	13/32	.40625	21/32	.65625	29/32	.90625
11/64	.17187	27/64	.42187	43/64	.67187	59/64	.92187
3/16	.18750	7/16	.43750	11/16	.68750	15/16	.93750
13/64	.20312	29/64	.45312	45/64	.70312	61/64	.95312
7/32	.21875	15/32	.46875	23/32	.71875	31/32	.96875
15/64	.23437	31/64	.48437	47/64	.73437	63/64	.98437
1/4	.25000	1/2	.50000	3/4	.75000	1 inch	1.00000

INCHES AND FRACTIONS IN DECIMALS OF A FOOT

Parts of Foot in Inches and Fractions	Decimal of a Foot	Parts of Foot in Inches and Fractions	Decimal of a Foot	Parts of Foot in Inches and Fractions	Decimal of a Foot	Parts of Foot in Inches and Fractions	Decimal of a Foot
1/16	.00520	3 1/16	.25520	6 1/16	.50520	9 1/16	.75520
1/8	.01040	3 1/8	.26040	6 1/8	.51040	9 1/8	.76040
3/16	.01562	3 3/16	.26562	6 3/16	.51562	9 3/16	.76562
1/4	.02080	3 1/4	.27080	6 1/4	.52080	9 1/4	.77080
5/16	.02600	3 5/16	.27600	6 5/16	.52600	9 5/16	.77600
3/8	.03125	3 3/8	.28125	6 3/8	.53125	9 3/8	.78125
7/16	.03640	3 7/16	.28650	6 7/16	.53640	9 7/16	.78650
1/2	.04170	3 1/2	.29170	6 1/2	.54170	9 1/2	.79170
9/16	.04687	3 9/16	.29687	6 9/16	.54687	9 9/16	.79687
5/8	.05210	3 5/8	.30210	6 5/8	.55210	9 5/8	.80210
11/16	.05730	3 11/16	.30730	6 11/16	.55730	9 11/16	.80730
3/4	.06250	3 3/4	.31250	6 3/4	.56250	9 3/4	.81250
13/16	.06770	3 13/16	.31770	6 13/16	.56770	9 13/16	.81770
7/8	.07290	3 7/8	.32290	6 7/8	.57290	9 7/8	.82290
15/16	.07812	3 15/16	.32812	6 15/16	.57812	9 15/16	.82812
1 inch	.08330	4 inches	.33330	7 inches	.58330	10 inches	.83330
1 1/16	.08850	4 1/16	.33850	7 1/16	.58850	10 1/16	.83850
1 1/8	.09375	4 1/8	.34375	7 1/8	.59375	10 1/8	.84375
1 3/16	.09900	4 3/16	.34900	7 3/16	.59900	10 3/16	.84900
1 1/4	.10420	4 1/4	.35420	7 1/4	.60420	10 1/4	.85420
1 5/16	.10937	4 5/16	.35937	7 5/16	.60937	10 5/16	.85937
1 3/8	.11460	4 3/8	.36460	7 3/8	.61460	10 3/8	.86460
1 7/16	.11980	4 7/16	.36980	7 7/16	.61980	10 7/16	.86980
1 1/2	.12500	4 1/2	.37500	7 1/2	.62500	10 1/2	.87500
1 9/16	.13020	4 9/16	.38020	7 9/16	.63020	10 9/16	.88020
1 5/8	.13540	4 5/8	.38540	7 5/8	.63540	10 5/8	.88540
1 11/16	.14062	4 11/16	.39062	7 11/16	.64062	10 11/16	.89062
1 3/4	.14580	4 3/4	.39580	7 3/4	.64580	10 3/4	.89580
1 13/16	.15100	4 13/16	.40100	7 13/16	.65100	10 13/16	.90100
1 7/8	.15625	4 7/8	.40625	7 7/8	.65625	10 7/8	.90625
1 15/16	.16150	4 15/16	.41140	7 15/16	.66150	10 15/16	.91150
2 inches	.16670	5 inches	.41670	8 inches	.66670	11 inches	.91670
2 1/16	.17187	5 1/16	.42187	8 1/16	.67187	11 1/16	.92187
2 1/8	.17710	5 1/8	.42710	8 1/8	.67710	11 1/8	.92710
2 3/16	.18230	5 3/16	.43230	8 3/16	.68230	11 3/16	.93230
2 1/4	.18750	5 1/4	.43750	8 1/4	.68750	11 1/4	.93750
2 5/16	.19270	5 5/16	.44270	8 5/16	.69270	11 5/16	.94270
2 3/8	.19790	5 3/8	.44790	8 3/8	.69790	11 3/8	.94790
2 7/16	.20312	5 7/16	.45312	8 7/16	.70312	11 7/16	.95312
2 1/2	.20830	5 1/2	.45830	8 1/2	.70830	11 1/2	.95830
2 9/16	.21350	5 9/16	.46350	8 9/16	.71350	11 9/16	.96350
2 5/8	.21875	5 5/8	.46875	8 5/8	.71875	11 5/8	.96875
2 11/16	.22400	5 11/16	.47400	8 11/16	.72400	11 11/16	.97400
2 3/4	.22920	5 3/4	.47920	8 3/4	.72920	11 3/4	.97920
2 13/16	.23437	5 13/16	.48437	8 13/16	.73437	11 13/16	.98437
2 7/8	.23950	5 7/8	.48960	8 7/8	.73960	11 7/8	.98960
2 15/16	.24480	5 15/16	.49480	8 15/16	.74480	11 15/16	.99480
3 inches	.25000	6 inches	.50000	9 inches	.75000	12 inches	1.00000

Metric Conversion Table

Millimeters	×	.03937	=	Inches
"	=	25.400	×	"
Meters	×	3.2809	=	Feet
"	=	.3048	×	"
Kilometers	×	.621377	=	Miles
"	=	1.6093	×	"
Square centimeters . . .	×	.15500	=	Square inches
" " . . .	=	6.4515	×	" "
Square meters	×	10.76410	=	Square feet
" "	=	.09290	×	" "
Square kilometers . . .	×	247.1098	=	Acres
" " . . .	=	.00405	×	"
Hectares	×	2.471	=	"
"	=	.4047	×	"
Cubic centimeters . . .	×	.061025	=	Cubic inches
" " . . .	=	16.3866	×	" "
Cubic meters	×	35.3156	=	Cubic feet
" "	=	.02832	×	" "
" "	×	1.308	=	Cubic yards
" "	=	.765	×	" "

Liters	×	61.023	=	Cubic inches
"	=	.01639	×	" "
"	×	.26418	=	U. S. gallons
"	=	3.7854	×	" "
Grams	×	15.4324	=	Grains
"	=	.0648	×	"
"	×	.03527	=	Ounces, av'dupois
"	=	28.3495	×	" "
Kilograms	×	2.2046	=	Pounds
"	=	.4536	×	"
Kilog's per sq. centimeter .	×	14.2231	=	Lbs. per sq. inch
" " "	=	.0703	×	" "
Kilogram per cubic meter	×	.06243	=	Lbs. per cubic foot
" " "	=	16.01890	×	" "
Metric tons (1,000 kilog's)	×	1.1023	=	Tons (2,000 lbs.)
" "	=	.9072	×	" "
Kilowatts	×	1.3405	=	Horse-powers
"	=	.746	×	"
Calories	×	3.9683	=	B. T. units
"	=	.2520	×	"
Francs	×	.193	=	Dollars
"	=	5.18	×	"

METRIC CONVERSION TABLE

Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
1/16	1.59	2 5/16	58.74	6	152.40
1/8	3.17	2 3/8	60.33	6 1/4	158.75
3/16	4.76	2 7/16	61.91	6 1/2	165.10
1/4	6.35	2 1/2	63.50	6 3/4	171.45
5/16	7.94	2 9/16	65.09	7	177.80
3/8	9.53	2 5/8	66.67	7 1/4	184.15
7/16	11.10	2 11/16	68.26	7 1/2	190.50
1/2	12.70	2 3/4	69.85	7 3/4	196.85
9/16	14.29	2 13/16	71.44	8	203.20
5/8	15.87	2 7/8	73.03	8 1/4	209.55
11/16	17.46	2 15/16	74.61	8 1/2	215.90
3/4	19.05	3	76.20	8 3/4	222.25
13/16	20.64	3 1/8	79.37	9	228.60
7/8	22.23	3 1/4	82.55	9 1/4	234.95
15/16	23.81	3 3/8	85.73	9 1/2	241.30
1	25.40	3 1/2	88.90	9 3/4	247.65
1 1/16	26.99	3 5/8	92.08	10	254.00
1 1/8	28.57	3 3/4	95.25	10 1/4	260.35
1 3/16	30.16	3 7/8	98.43	10 1/2	266.70
1 1/4	31.75	4	101.60	10 3/4	273.05
1 5/16	33.34	4 1/8	104.78	11	279.40
1 3/8	34.92	4 1/4	107.95	11 1/4	285.75
1 7/16	36.51	4 3/8	111.13	11 1/2	292.10
1 1/2	38.10	4 1/2	114.30	11 3/4	298.45
1 9/16	39.68	4 5/8	117.48	12	304.80
1 5/8	41.27	4 3/4	120.65	13	330.20
1 11/16	42.86	4 7/8	123.83	14	355.60
1 3/4	44.44	5	127.00	15	381.00
1 13/16	46.03	5 1/8	130.18	16	406.40
1 7/8	47.62	5 1/4	133.35	17	431.80
1 15/16	49.21	5 3/8	136.53	18	457.20
2	50.80	5 1/2	139.70	19	482.60
2 1/16	52.39	5 5/8	142.88	20	508.00
2 1/8	53.97	5 3/4	146.05		
2 3/16	55.56	5 7/8	147.25	39.3708	1. Meter
2 1/4	56.15				

1 Kilogramme = 2.2046 Lb.
50,8 Kilogrammes = 1 Cwt.
100 Kilogrammes = 1,96 Cwts.
1000 Kilogrammes = 19,68 Cwts.
1016,06 Kilogrammes = 1 Ton.
1.0 Cubic Meter = 35,317 Cubic Feet

AREAS AND CIRCUMFERENCES OF CIRCLES

Diameter	Area	Circumference	Diameter	Area	Circumference
1	.7854	3.1416	51	2042.8206	160.2212
2	3.1416	6.2832	52	2123.7166	163.3628
3	7.0686	9.4248	53	2206.1834	166.5044
4	12.5664	12.5664	54	2290.2210	169.6460
5	19.6350	15.7080	55	2375.8294	172.7876
6	28.2743	18.8496	56	2463.0086	175.9292
7	38.4845	21.9911	57	2551.7586	179.0708
8	50.2655	25.1327	58	2642.0794	182.2184
9	63.6173	28.2743	59	2733.9710	185.3540
10	78.5398	31.4159	60	2827.4334	188.4956
11	95.0332	34.5575	61	2922.4666	191.6372
12	113.0973	37.6991	62	3019.0705	194.7787
13	132.7323	40.8407	63	3117.2453	197.9203
14	153.9380	43.9823	64	3216.9909	201.0619
15	176.7146	47.1239	65	3318.3072	204.2035
16	201.0619	50.2655	66	3421.1944	207.3451
17	226.9801	53.4071	67	3525.6524	210.4867
18	254.4690	56.5487	68	3631.6811	213.6283
19	283.5287	59.6903	69	3739.2807	216.7699
20	314.1593	62.8319	70	3848.4510	219.9115
21	346.3606	65.9734	71	3959.1921	223.0531
22	380.1327	69.1150	72	4071.5041	226.1947
23	415.4756	72.2566	73	4185.3868	229.3363
24	452.3893	75.3982	74	4300.8403	232.4779
25	490.8739	78.5398	75	4417.8647	235.6194
26	530.9292	81.6814	76	4536.4598	238.7610
27	572.5553	84.8230	77	4656.6257	241.9026
28	615.7522	87.9646	78	4778.3624	245.0442
29	660.5199	91.1062	79	4901.6699	248.1858
30	706.8583	94.2478	80	5026.5482	251.3274
31	754.7676	97.3894	81	5152.9974	254.4690
32	804.2477	100.5310	82	5281.0173	257.6106
33	855.2986	103.6726	83	5410.6079	260.7522
34	907.9203	106.8142	84	5541.7694	263.8938
35	962.1128	109.9557	85	5674.5017	267.0354
36	1017.8760	113.0973	86	5808.8048	270.1770
37	1075.2101	116.2389	87	5944.6787	273.3186
38	1134.1149	119.3805	88	6082.1234	276.4602
39	1194.5906	122.5221	89	6221.1389	279.6017
40	1256.6371	125.6637	90	6361.7251	282.7434
41	1320.2543	128.8053	91	6503.8822	285 8849
42	1385.4424	131.9469	92	6647.6101	289.0265
43	1452.2012	135.0835	93	6792.9097	292.1681
44	1520.5308	138.2301	94	6939.7782	295.3097
45	1590.4313	141.3717	95	7088.2184	298.4513
46	1661.9025	144.5133	96	7238.2295	301.5929
47	1734.9445	147.6549	97	7389.8113	304.7345
48	1809.5574	150.7964	98	7542.9610	307.8761
49	1885.7410	153.9380	99	7697.6874	311.0177
50	1963.4954	157.0796	100	7853.9816	314.1593

FRESH WATER
UNITED STATES GALLON

Tons = gallons / 268.365

Tons = cubic feet / 35.883

Pounds = cubic feet × 62.425
Gallons = cubic feet × 7.48
Pressure = height in feet × .4335
Height in feet = pressure × 2.3093

	Logarithm
1 ton contains 35.883 cubic feet	1.55489
1 ton contains 268.365 gallons	2.56628
1 ton weighs 2240 pounds	3.35025
1 gallon contains 231 cubic inches	2.36361
1 gallon contains .833 imperial gallon	2.92065
1 gallon weighs 8.33 pounds	.92065
1 quart weighs 2.08 pounds	.31806
1 pint weighs 1.04 pounds	.01703
1 gill weighs .26 pound	9.41497
1 cubic foot weighs 62.425 pounds	1.79536
1 cubic foot contains 7.48 gallons	.87390
1 cubic foot contains 1728 cubic inches	3.23754
1 cubic inch weighs .036125 pound	8.55781
12 cubic inches weighs .4335 pound	9.63699
27.71 cubic inches weighs 1 pound	
27.71 cubic inches, height 2.3093 feet	.36348

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