LAYING OFF

OR

THE GEOMETRY OF SHIPBUILDING

EDWARD L. ATTWOOD
AND
I. C. G. COOPER

A TEXT-BOOK OF LAYING OFF

Mould Loft Floor at Messrs. Vickers' Shipyard, Barrow-in-Furness. [*Frontispiece.*

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THE GEOMETRY OF SHIPBUILDING

BY

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PREFACE

THE writers have long been of the opinion that a new work on the subject of "Laying Off," adapted for the use of students, had become necessary. It came to their knowledge that both were engaged in preparing such a text-book, and this led to a collaboration, the present work being the result.

One difficulty in the preparation of such a book is that practice varies considerably in different building yards and in different shipbuilding centres. The principle adopted has been to describe processes and methods which are known to the authors and which are found to be satisfactory in practice. If other methods come under the reader's notice they may be compared with those indicated herein.

It has been thought desirable to provide an introductory chapter on the principles of "descriptive geometry" in order to lay a satisfactory foundation of knowledge for the subsequent work.

Although the work of "laying off" is mainly done by a special class of skilled workmen, it is considered very desirable that ship draughtsmen and students of Naval Architecture should have an acquaintance with the subject. In many cases it is not found possible for such students actually to do work themselves on the mould loft floor. It is hoped that the present work will be found useful to this large class.

It is strongly recommended that students, in addition to reading the text, should draw out for themselves the various examples that are scattered throughout the book.

The drawings illustrating the text are very numerous, and have been very carefully drawn, and care has been taken in the lettering, etc., in order to make the illustrations self-explanatory as far as possible. Students requiring a knowledge of the special and difficult laying-off problems connected with wood shipbuilding are referred to Dr. Thearle's valuable work on "Naval Architecture."

The photograph of the Barrow Mould Loft which forms the frontispiece is reproduced by the kind permission of W. T. Davis, Esq., the Shipyard Manager.

E. L. ATTWOOD.
I. C. G. COOPER.

PREFACE TO THE SECOND EDITION

THE call for a second edition of this work shows that there was a need for a book of this character, and the Authors acknowledge with thanks many suggestions received, which so far as possible have been embodied. The opportunity has been taken to revise slightly some portions of the text with a view to greater clearness, and some additions have been made thereto. In particular, the solution of the Hawse Pipe problem given in Chapter VI. has been modified so as to embody a theoretically correct method of projecting the generators of the cylinder; the principle of the method being given in the addition to Chapter I. Some new examples have been included.

E. L. ATTWOOD.
I. C. G. COOPER.

Built for freight and yet for speed,
A beautiful and gallant craft;
Broad in the beam, that the stress of the blast,
Pressing down upon sail and mast,
Might not the sharp bows overwhelm;
Broad in the beam, but sloping aft
With graceful curve and slow degrees,
That she might be docile to the helm,
And that the currents of passing seas,
Closing behind, with mighty force,
Might aid and not impede her course.

* * * * *

Then the Master
With a gesture of command
Waved his hand;
And at the word,
Loud and sudden there was heard,
All around them and below,
The sound of hammers, blow on blow,
Knocking away the shores and spurs.
And see! she stirs!
She starts—she moves—she seems to feel
The thrill of life along her keel,
And, spurning with her foot the ground,
With one exulting, joyous bound,
She leaps into the ocean's arms!
How beautiful she is! How fair
She lies within those arms, that press
Her form with many a soft caress
Of tenderness and watchful care!
Sail forth into the sea, O ship!
Through wind and wave, right onward steer.
The moistened eye, the trembling lip,
Are not the signs of doubt or fear.

From Longfellow's "The Building of the Ship."

CONTENTS

ILLUSTRATIONS

TEXT-BOOK OF LAYING OFF

CHAPTER I

DESCRIPTIVE GEOMETRY

THE term "laying off" is used to describe the methods adopted to obtain the form of a ship so that in the shipyard the materials can be shaped piece by piece, and after erection at the ship the required fair ship-shape structure will be obtained.

Laying off is really the application of the principles of Descriptive Geometry to the particular case of a ship. We therefore start by taking up the elements of this subject, passing on later to the actual problems and processes required in laying off a ship.

Descriptive Geometry.—The position of a point in space is fully determined when its distances from three planes of reference are given, which planes are usually taken at right angles to one another. Thus if we are told that a certain point in a room is 3 ft. from the floor, this only locates the point so far as its inclusion in a horizontal plane is concerned. If, in addition, we are told that the point is 5 ft. from the south wall, then all points on a certain line will satisfy the condition. If a third condition is given, viz. that the point is also 4 ft. from the east wall, the position of the point in space is absolutely fixed.

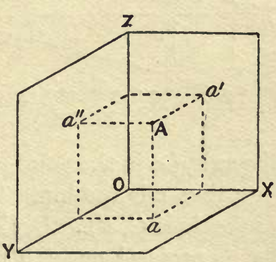


FIG. 1.

In Fig. 1, YX is the horizontal plane, XZ the longitudinal vertical plane, and YZ the transverse vertical plane. If perpendiculars are drawn from the point A on to these planes of reference, then the feet of these perpendiculars a, a', a'' are the *projections* of the point A. The projection of a line on a plane is the line passing through the feet of all perpendiculars drawn from the line on to the plane, and the projection of a straight line on to a plane must also be a straight line. Except for special purposes we only use the longitudinal vertical plane as XZ (written V.P.) and the horizontal plane as XY (written H.P.). Projections on the H.P. are denoted by small letters and on the V.P. by small letters with a single dash. Thus the point A has a horizontal projection (h.p.) *a* and a vertical projection (v.p.) *a'*.

In order to enable us to represent the planes of reference on a flat surface, the V.P. is supposed to be in the paper, and the H.P. is supposed to be hinged down about its junction with the V.P. on to the paper. Thus a point A 3 in. from the H.P. and 2 in. from the V.P., will be represented in our drawing by its projections *a* and *a'* as Fig. 2. The junction of the H.P. and the V.P., viz. X'X, is termed the *axis* or *ground line.*

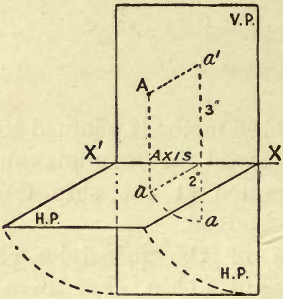


FIG. 2.

Definition.—The trace of a line upon a given plane is the point where the line or the line produced meets the plane.

Problem.—**To find the traces of a line AB given by its projections** (*ab, a'b'*) (Fig. 3).

Let C be the horizontal trace of the line AB, then this point C must be—

(i) *in* the H.P., and therefore its v.p. must be in the axis; and

(ii) in AB produced, and therefore its v.p. must be in *a'b'* produced.

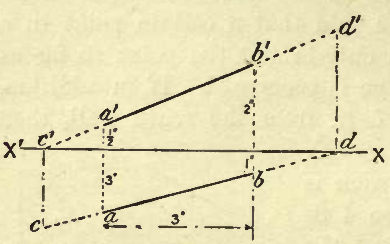


FIG. 3.

Therefore the v.p. of C must be where *a'b'* produced meets the axis, *i.e.* in the point *c'*. If we square *c'* down to meet *ab* produced in *c*, then *c* is the h.p. Thus C is the horizontal trace given by its projections (*c*, *c'*). D, the vertical trace, is found in the same way by its projections (*d*, *d'*).

EXAMPLE.—A line AB is given by its v.p. *a'b'* and its h.p. *ab*, as shown in Fig. 3. Find the distance of its horizontal and vertical traces respectively from the axis. *Ans.* 3·7 in., 2·75 in.

The above construction fails when the line is in a plane perpendicular to the axis.

Let AB be such a line (Fig. 4), the projections (ab, $a'b'$) being perpendicular to the axis. Imagine the line AB to be hinged about its h.p. ab, on to the H.P. This hinging is termed *rabatting*. Trace the movement of the point A. It will move in a circular arc, and the h.p. of its path must be perpendicular to ab and the length of the perpendicular must equal the height of A above the H.P., *i.e* $a'c'$, therefore make $a\text{A} = a'c'$. Similarly $b\text{B} = b'c'$. Join AB, then AB is the *true length* of the line AB. Produce AB both ways to C and E. If now we imagine the line AB hinged back, E will move up to e' about the centre c' and C will remain where it is. Thus the horizontal trace is the point (c, c') and the vertical trace is the point (e, e').

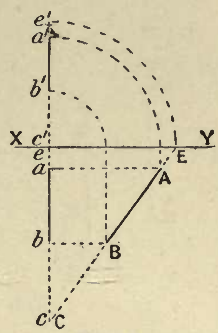


Fig. 4.

Problem.—**To find the *true length* of a line AB given by its projections** (ab, $a'b'$) (Fig. 5).

The process adopted is to *rabat* the line AB on to the H.P. about ab. Draw bB and aA perpendicular to ab. Make bB and aA of lengths equal to the heights of b' and a' above the H.P. Join AB. Then AB will give the *true length*.

The same result would be obtained by *rabatting* the line about the vertical projection on to the V.P.

The angle between ab and AB produced must be the angle the line makes with the H.P., viz. θ, and the angle between $a'b'$ and AB must be the angle the line makes with the V.P., viz. ϕ.

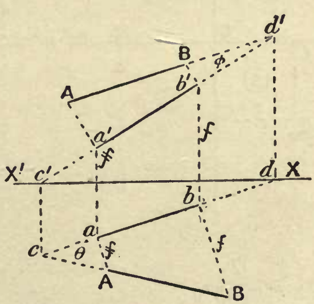


Fig. 5.

Example.—Three points, A, B, C, are given by their projections (a, a'), (b, b'), and (c, c') in Fig. 6. Give in inches the lengths of the lines AB, BC, and CA, and state in degrees the angle which the line AB makes with the V.P.
Ans. 1·5, 3·9, 4·3 in.; $41\frac{1}{2}°$.

Example.—Find in a separate figure the vertical traces of the lines AB and BC of the previous example.

It does not always happen that the horizontal projection of a point will be below the axis or the vertical projection above the axis. This will only be the case for a point in the first quadrant as A (Fig. 7). A point B in the second quadrant will have its projections as *b*, *b′*. A point C in the third quadrant has projections *c*, *c′*. A point D in the fourth quadrant has its projections *d*, *d′*.

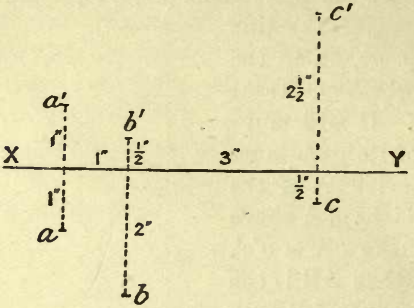


FIG. 6.

EXAMPLE.—Find the traces of the line AB given by its projections (*ab*, *a′b′*) (Fig. 8).

Ans. (*c*, *c′*) is the H.T. and (*d*, *d′*) the V.T.

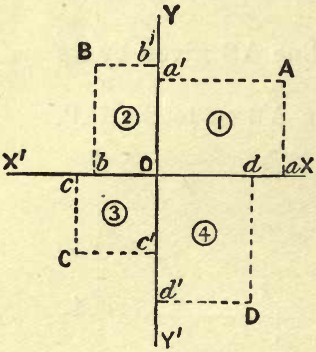
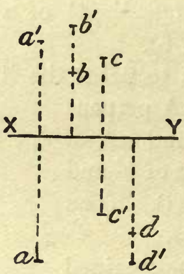


FIG. 7.



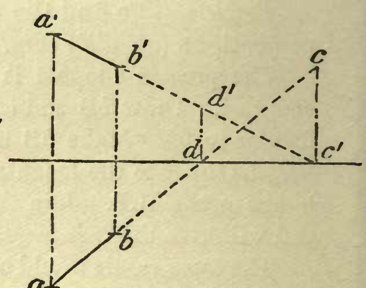


FIG. 8.

EXAMPLE.—Three points A, B, C are given by their projections (*a*, *a′*), (*b*, *b′*), (*c*, *c′*) in Fig. 9. Find the vertical and horizontal traces of the lines AB, BC, and CA, and check your results by drawing straight lines through the v p. of vertical traces and the h.p. of the horizontal traces. (The vertical traces are (*d*, *d′*), (*g*, *g′*) and (*k*, *k′*), and *d′g′k′* is a straight line. The horizontal traces are (*e*, *e′*), (*f*, *f′*) and (*h*, *h′*), and *feh* is a straight line.)

Definition.—The traces of a plane are the lines in which the plane meets the planes of reference. A plane is determined by its traces as in Fig. 10, PQ is the horizontal trace, and QR the vertical trace of the plane PQR.

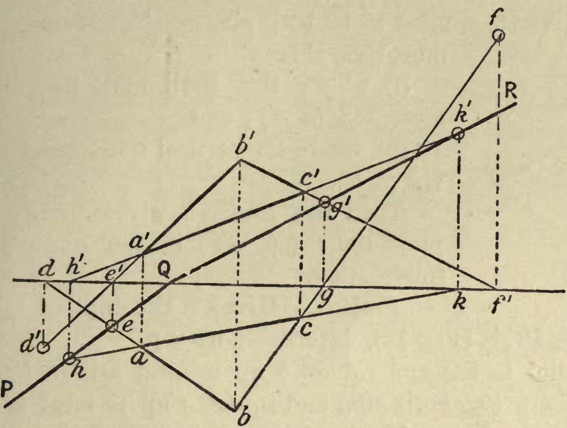


Fig. 9.

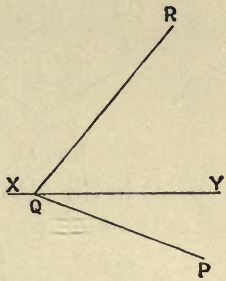


Fig. 10.

Problem.—**To determine the angle between the plane PQR** (Fig. 11) **and the H.P.**

The point (b, b') is a point in the vertical trace. Draw ba perpendicular to the horizontal trace PQ. Then (aa') is a point in the horizontal trace PQ, and the line AB is a line *in* the plane perpendicular to the horizontal trace PQ. With b as centre and radius ba describe a circular arc meeting the axis in A. Join b'A. Then the angle θ which b'A makes with the axis is the angle required. Imagine a piece of cardboard cut out to the shape bb'A, and hinged round about bb'. Then it will just tuck in under the plane PQR when the plane of the cardboard is perpendicular to the plane PQR.

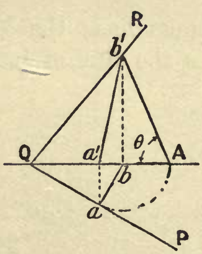


Fig. 11.

The angle a plane makes with the vertical plane may be found in a similar manner.

Example.—A plane is given by its traces PQ and QR such that PQ makes an angle with the axis of 30° and QR an angle with the axis of 45°, the angle PQR being 75°. Find the angles the plane makes with the H.P. and the V.P. respectively. *Ans.* $63\frac{1}{2}°$, $39\frac{1}{4}°$.

Problem.—**To determine the line of intersection of two planes PQR, STU** (Fig. 12).

The line of intersection must be in both planes. Therefore it must pass through—

(i) where the horizontal traces meet, viz. (a, a') ; and

(ii) where the vertical traces meet, viz. (b, b').

Then the line AB given by its projections $(ab, a'b')$ is the line of intersection.

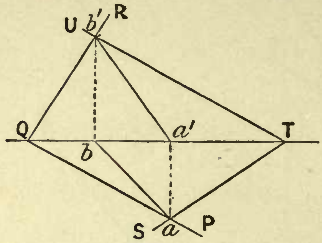


Fig. 12.

Problem.—**Given a the h.p. of a point in the plane PQR (Fig. 13), determine its v.p.**

Draw ab parallel to PQ and square b up to meet QR in b'. Draw $b'a'$ horizontal and square a up to meet it in a'. Then a' is the point required.

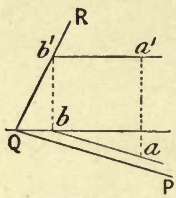


Fig. 13.

Problem.—**To find the point of intersection of the line AB given by its projections $(ab, a'b')$ and the plane PQR (Fig. 14).**

Pass a vertical plane STU through the line AB. Its horizontal trace must coincide with the h.p. of the line ab, and its vertical trace must meet the V.P. in a vertical line. Then the line $(cd, c'd')$ is the line of intersection of the planes PQR and STU. Then the lines $(ab, a'b')$ and $(cd, c'd')$ are both in the plane STU and therefore they must intersect. But $(cd, c'd')$ is also in the plane

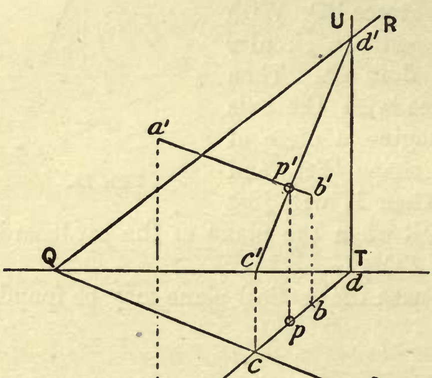


Fig. 14.

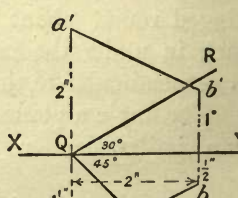


Fig. 15.

PQR. Therefore the intersection of $(ab, a'b')$ and $(cd, c'd')$ is on the line $(ab, a'b')$ and also in the plane PQR. The point (p, p')

therefore is the intersection required of the plane PQR and the line AB.

EXAMPLE.—Determine the perpendicular distance of the intersection of the plane PQR and the line AB from the axis (Fig. 15). *Ans.* 1·05 in.

Problem.—**To determine the perpendicular distance of the point** (a, a') **from the plane PQR** (Fig. 16).

The first thing to do is to find the foot of the perpendicular drawn from (a, a') on to the plane PQR.

If a line is perpendicular to a plane it must be perpendicular to every line in the plane. Also if a line is perpendicular to a plane the projections of the line are perpendicular to the traces of the plane.

From (a, a') draw ab, $a'b'$ perpendicular to the traces PQ, QR. Then the line $(ab, a'b')$ is a line perpendicular to the plane PQR. Then by the construction given in the previous problem the point (e, e') is the intersection of the line AB with the plane PQR, and this point is the foot of the perpendicular required. It only remains to rabat AE about its h.p. on to the horizontal plane. Draw eE, aA perpendicular to ae and make eE, aA equal respectively to the heights of e' and a' about the axis. Then EA is the true length required.

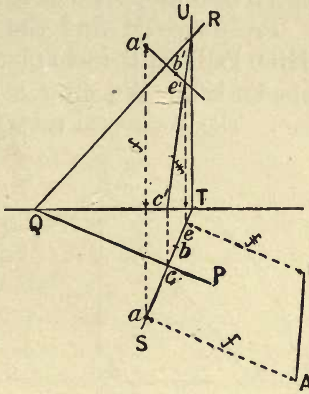


FIG. 16.

Problem.—**To pass a plane through the three points** (a, a'), (b, b'), **and** (c, c') (Fig. 9).

The horizontal trace of the line AB being the point where it meets the H.P., this horizontal trace must be in the horizontal trace of the plane required. Similarly for the vertical trace.

Therefore find the horizontal and vertical traces of any two of the lines AB, BC, and CA, and the line joining the horizontal traces thus found will be the horizontal trace of the plane required, and the line joining the vertical traces will be the vertical trace of the plane required.

The horizontal trace of AB is the point (e, e'). The horizontal trace of AC is (h, h'). A line through e and h therefore gives the horizontal trace of the plane required, viz. PQ. The vertical trace of AC is the point (k, k'), and of the line BC is the point (g, g'). A line through g' and k' therefore gives the vertical trace of the plane required, viz. QR. PQR is therefore the plane passing through the three points A, B, and C, given by its traces PQ and QR. It will be noticed that the lines through e and h and through g' and k' must necessarily meet the axis in the same point Q. Also PQ produced passes through f, the horizontal projection of the horizontal trace of BC, and QR produced passes through d', the vertical projection of the vertical trace of AB.

Problem.—**To find the Angle between Two Planes.**—Let MNO, PQR be the two planes (Fig. 17). The line $(ab, a'b')$ is the intersection. We draw a plane perpendicular to this intersection. The horizontal trace of this plane must be perpendicular to ab. Such a line as DE can be taken as this horizontal trace meeting ab in c. The plane through DE perpendicular to $(ab, a'b')$ will meet the two planes in two lines, the angle between which will be the angle required. These two lines meet the H.P. in the points D and E. Imagine a perpendicular drawn from c to the line $(ab, a'b')$. The foot of this perpendicular is rabatted into the position H given by the following construction. Rabat $(ab, a'b')$ on to the H.P., making $bB = bb'$, and draw cH perpendicular to aB. If the perpendicular plane is rabatted on to the H.P. about DE, the intersection with $(ab, a'b')$ will take up the position H′ where cH′ = cH. The angle DH′E is therefore the angle required.

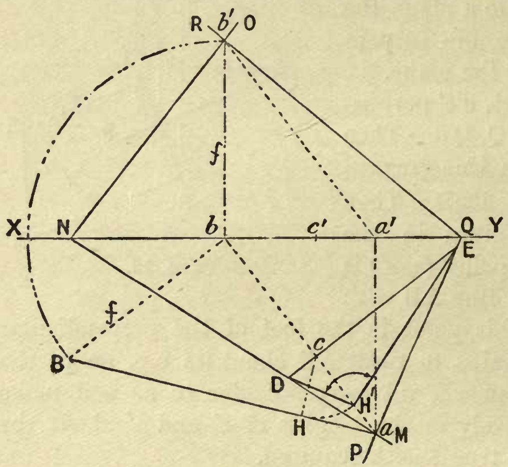


FIG. 17.

Problem.—**To find the shortest distance between two lines, AB and CD, which do not meet, and which are not parallel.**

It will be useful to discuss this first with the aid of a perspective figure before dealing with it by the principles of descriptive geometry.

The shortest distance between two such straight lines is the straight line which cuts both of them at right angles. Let AB and CD be the two lines (Fig. 18 (a)). Through any point A in AB draw AE parallel to CD, and pass a plane through EAB, which is therefore parallel to CD. Through any point F in CD draw FG perpendicular to the plane EAB, the foot of this perpendicular being G. From G draw a line in the plane BAE parallel to AE or CD. This line GH must meet AB, say in H, because AB and GH are in the same plane, and are not parallel. From H draw

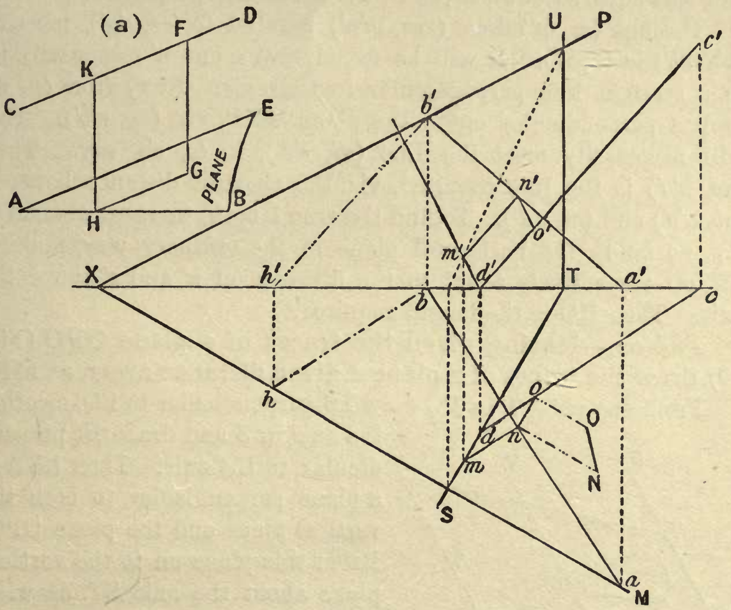


FIG. 18.

HK parallel to GF. Then HK is in the plane through CFG, and must meet CD in the point K, say. Then HK is perpendicular to AB, since it is perpendicular to the plane through EAB, and it is also perpendicular to CD because CD is parallel to AE, a line in the plane through EAB. HK is therefore perpendicular to both lines AB and CD, and is the shortest distance between them.

Now, to deal with this problem by the methods of descriptive geometry. Let (*ab*, *a'b'*), (*cd*, *c'd'*) be the two lines which do not meet and which are not parallel (Fig. 18). Through any point in (*ab*, *a'b'*), the vertical trace (*b*, *b'*), say, draw a line parallel to (*cd*, *c'd'*). Through *b* draw *bh* parallel to *cd*, and through *b'* draw *b'h'* parallel to *c'd'*. Then through the lines (*ab*, *a'b'*) and (*bh*, *b'h'*) draw a plane, viz. MXP. This plane is parallel to (*cd*, *c'd'*), since it contains a line (*bh*, *b'h'*) parallel to (*cd*, *c'd'*). Through any point in (*cd*, *c'd'*), its horizontal trace (*d*, *d'*), for example, draw a perpendicular to the plane MXP (*dm*, *d'm'*). The foot of this perpendicular is found by passing a vertical plane through it, viz. STU. The intersection of this plane with MXP will give the point *m'* for the vertical projection of the foot of the perpendicular, and this squared down gives *m*, the horizontal projection.

Through (*m*, *m'*) draw (*mn*, *m'n'*) parallel to (*cd*, *c'd'*), meeting (*ab*, *a'b'*) in (*n*, *n'*). It will be found that *n* and *n'* necessarily lie in a straight line perpendicular to the axis. Now, from (*n*, *n'*) drop a perpendicular on to the plane MXP, viz. (*no*, *n'o'*). This will necessarily meet the line (*cd*, *c'd'*), in (*o*, *o'*), say. Then (*no*, *n'o'*) is the line required, viz. the shortest distance between (*ab*, *a'b'*) and (*cd*, *c'd'*). To find the true length, we rabat about the h.p. *no* on to the horizontal plane in the ordinary way, making *n*N, *o*O respectively equal to the distance of *n'* and *o'* above the axis. Then NO is the length required.

Problem.—**Having given the traces of a plane OPQ** (Fig. 10), **draw the traces of a plane a given distance away, as MN.**

From any point T in PQ draw TS perpendicular to PQ, meeting the axis in S and draw SR perpendicular to the axis. Then RST is a plane perpendicular to both the vertical plane and the plane OPQ. Rabat this plane on to the vertical plane about the axis ST, drawing SA perpendicular to ST and making SA = S*a*. Join TA. Then TA is the rabatment of the intersection of the plane RST with OPQ. From T draw TB perpendicular to TA and equal to the required distance MN, and draw BC parallel to TA. Then C is a point in the vertical trace of the required plane. Draw through C, UV for the vertical trace parallel to PQ, and UW parallel to PO for the horizontal trace. Then WUV is the plane required.

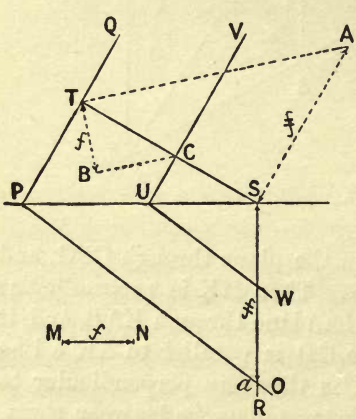


Fig. 19.

EXAMPLE.—Draw out the above example and check the result by using the method of Fig. 16 to determine the perpendicular distance between the two planes.

Problem.—**To develop the Surface of a Frustum of a Cone supposing the Apex is inaccessible.**—(In Fig. 20 the apex is accessible, but the figure has been thus drawn in order that the result may be checked.)

Method I. (Fig. 20).—Take any point E in the axis of the frustum ABCD and draw EF parallel to CD. This is the

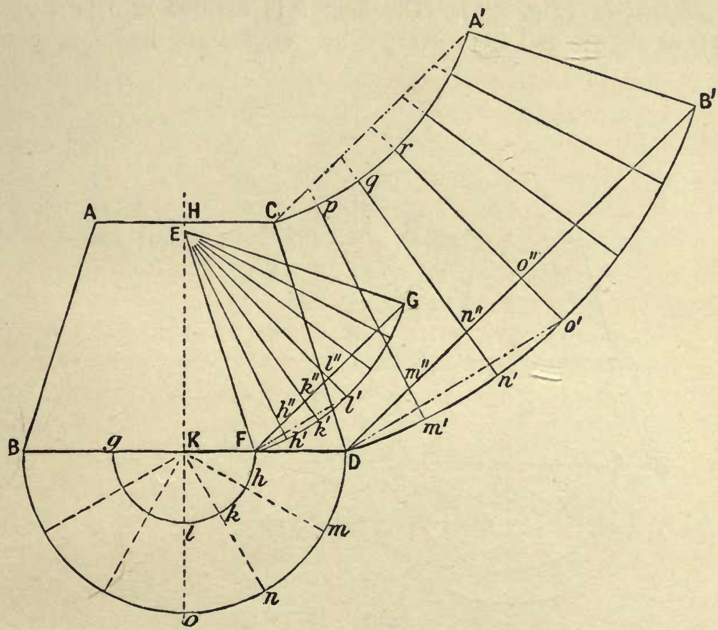


FIG. 20.

generator of a cone which is similar to the whole cone of which ABCD is a frustum.

Develop the surface of the small cone about EF by drawing the arc FG with centre E and of length equal to the length of the semicircle F*lg*. Join FG and draw in the radii E*h*′, E*k*′, etc., cutting the chord FG in *h*″, *k*″, etc. Then the development of the surface of the large cone will be exactly similar to that of the smaller cone. Draw DB′ parallel to FG and of length such that DB′ : FG : : DB : F*g*, *i.e.* in the proportion of the respective diameters of the bases of the two cones. Then divide DB′ at m'', n'', etc., in the same proportion as FG is divided in h'', k'', etc. Then the developed generators will pass through m'', n'', etc. Draw these generators parallel to the corresponding generators of the smaller cone. To end these draw chords as Do' parallel to Fl'. A curve through D$m'n'o'$ . . . B′ is the lower boundary. The upper boundary is found by making $m'p$, $n'q$, etc., equal to CD. The girth of Dm' . . . B′ will be, of course, equal to the girth of the semicircle DoB, and the development of half the surface of the frustum will be Do'B′A′rC.

Method II. (Fig. 20A).—The height is divided into two equal parts as shown, and the corresponding circles are drawn in plan;

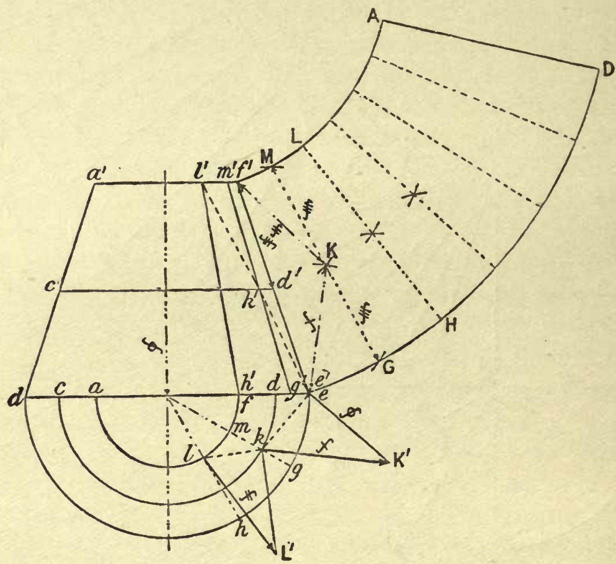


FIG. 20A.

equidistant radii are drawn at g and h, and the corresponding generators $g'm'$, $h'l'$ drawn in elevation.

Consider the element of the surface represented by $e'd'k'g'$ in elevation and $edkg$ in plan. The true length between (e, e') and (k, k') or (g, g') and (d, d') on the surface is very nearly that of the straight line between (g, g') and (d, d') or (e, e') and (k, k'), and is obtained by rabatting about ek as shown, giving the distance kK′. Similarly, lL′ gives the length between (k, k') and (l, l'). With centre e' and radius k'K′ strike in an arc at K, and with centre f' and radius lL′

strike in an arc cutting the previous arc at K. Then K will be the position of the point (k, k') when the surface is unwrapped. Similarly $d'G = kK'$ and $d'M = lL'$, also $KM = KG = a'c'$, and the arcs $e'G$ and $f'M$ are equal to eg and fm respectively. This will enable the first generator GM to be drawn in, and so on for the others.

Problem.—**To determine the projections of the generators of a cylinder having given the projections of the axis and its diameter.**

In Fig. 20B, ab and $a'b'$ are the plan and elevation of the axis

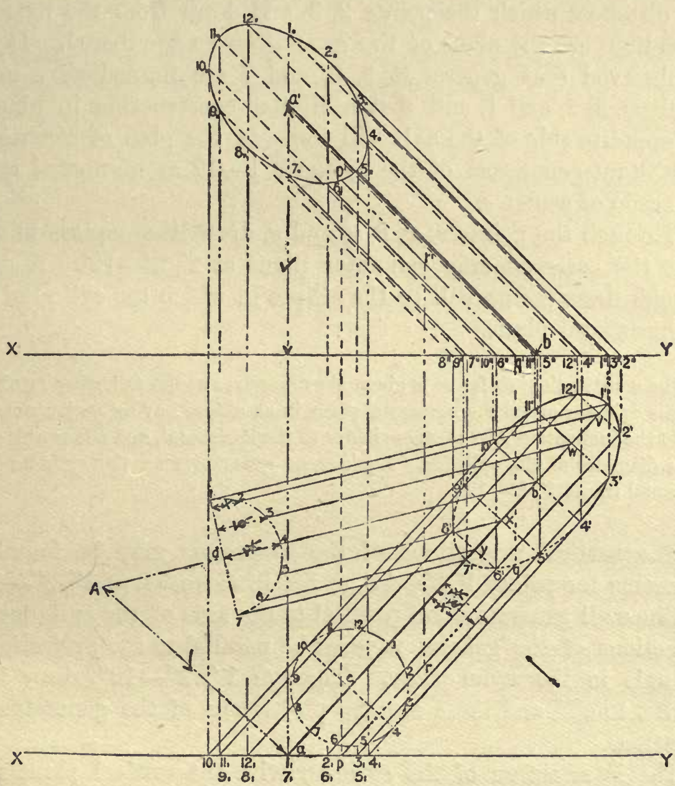


FIG. 20B.

of the cylinder, projected on the horizontal and vertical planes having ground line XY. Set up at right angles to ab, aA equal to the height of a' above XY. Join Ab; this is the real length of the part of the axis intercepted between the vertical and horizontal planes.

At any point *d* in A*b* draw 17 square to A*b* and describe on it a semicircle having the same diameter as the cylinder. Divide this semicircle into equal parts at 2, 3, 4, 5 and 6. Through the points 1—7, draw lines parallel to A*b* to meet *ab* produced in points *v*, *w*, *x*, etc. These lines will be the top (11′), bottom (77′), and intermediate equidistant generators on the surface of the cylinder, as seen when looking in the direction of the arrow, square to the axis of the cylinder.

Draw lines parallel to *ab* in plan and distant from it equal to the distances which the points 2, 3, and 4 are from the axis 17; these lines are the plans of the generators so numbered. It will be observed that generators 5, 6, and 7 are immediately under numbers 3, 2, and 1, and that a similar construction in plan on the opposite side of the axis will indicate the plan of a series of equidistant generators of the cylinder 1—12 as numbered round the circle of centre *e*.

Through the points *v*, *w*, *b*, *x*, and *y*, draw lines square to *ab* to meet the corresponding generator plans at 2′, 3′—12′. A curve through these points will be the ellipse in which the cylinder cuts the horizontal plane.

The construction, so far as is given above, arrives at the following result:—

The cylinder meets the horizontal plane in an ellipse having major axis 1′7′ due to the inclination Aba of the cylinder to the horizontal, and minor axis equal to the diameter of the cylinder. Equidistant generators on the cylinder have horizontal traces 1′, 2′—12′.

The vertical projections of the generators may be found by projecting the points 1′, 2′—12′, to XY in elevation at 1″, 2″—12″.

Since all generators are parallel to the axis of the cylinder, all projections of the generators must be parallel to the projection of the axis in the same plane. Through 1″, 2″—12″, draw lines parallel to *a′b′*, and these are the projections of the generators in elevation.

The intersection of the cylinder with the vertical plane may be found by projecting the point where each generator meets XY in plan, as 12 at $12_{,}$, to meet the elevation of the generator at $12_{,,}$. Note that $8_{,}$ and $8_{,,}$ will also be on the same line of projection. Draw a curve through all the points so obtained to determine the ellipse in which the cylinder cuts the vertical plane.

The projections of any other generator may be found if one point of it is known. Thus if r is any point on the cylinder, pq is the plan of the generator containing the point; and if q, where pq meets the ellipse, is projected to q', then $p'q'$ parallel to $a'b'$ is the elevation. The elevation of the point r will be at r'.

A similar problem for conical surfaces may be solved if it is remembered that all planes passing through the axis of the cone, cut the surface of the solid in straight lines. These lines all intersect at the apex. If the apex is not accessible, choose two sections of the cone as far apart as possible, and divide each of the circles into parts similar and similarly situated. Each generator must be considered separately.

EXAMPLE.—Draw out the projections of generators of a cone whose apex is inaccessible, and whose axis is inclined in both directions.

CHAPTER II

MOULD LOFT FLOOR AND APPLIANCES FOR LAYING OFF

Mould Loft Floor.—All shipbuilding yards have a special building called the "mould loft," on the floor of which vessels are laid off. This floor is a large clear space, well lighted, and the lines of the ship are drawn in upon it in chalk and faired. Where a floor is specially constructed for the purpose it is usually built up of planks about 6 in. wide and 3 in. thick, each plank being tongued and grooved at the edges. The butts of the planks are fitted as shown in Fig. 22; and all nails or screws should be sunk below the surface, the hole being filled in with a wood dowel similar to that in a wood deck. The floor should be laid on a substantial level foundation, and the surface well smoothed and covered with a flat black paint. In one yard the planks of the floor are laid at an angle, and this is stated to be a very convenient arrangement, as the ordinates are then quite clear of the plank edges and no confusion in this respect can arise.

Along each of the sides of the floor a fixed straight batten is secured from which measurements may be taken by simply forcing the end of the scale or batten against it. Considerable labour may be saved in this way as compared with having to set the end of the scale or batten to the base line on each occasion. The base line would be drawn at some even distance away from the fixed edge-batten. In one yard a sloping blackened board is fixed behind the edge batten on which numbers of stations can be chalked for convenience in placing the end of the scale or batten when lifting off distances from the edge, to ensure that the scale or batten lies along the ordinate.

To draw a Straight Line.—If short, this may be done with a *straight-edge,* but the usual method is to use a chalk line, and this is essential if the line is a long one. (The line recommended is No. 2 crotchet cotton.) To strike in a long straight line, the line (well chalked) is stretched tightly between the extreme points desired, and other persons stop the line at equal intervals by placing the finger carefully on the chalk line without shifting it. The line required can then be snapped in section by section. It is specially necessary to adopt this process if the floor is not perfectly level and even. A base line which is not absolutely straight will cause considerable trouble in all the subsequent work. It is as well to check a long straight line with three sights. Erect at each end on one side of the line a vertical batten. Outwind these two battens and approach a third from the opposite side of the line until the light is shut out. The edge of this batten should then coincide with the line on the floor.

To draw a Line square to another Line.—If this line is to be of any length it is undesirable to trust to the truth of a set-square, and the method of *horning* should be adopted as follows. Suppose it is required to draw a straight line square to XY through the point Z (Fig. 21). Mark off on each side of Z equal distances as ZA and ZB. With A and B as centres respectively, and at a convenient radius, make small arcs intersecting in C. Then the line joining CZ will be perpendicular to XY.

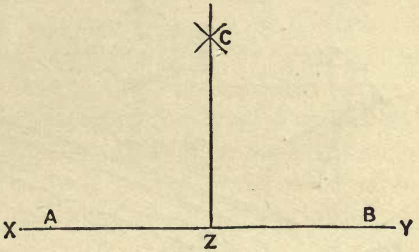


FIG. 21.

Distances are transferred from one part of the floor to another by using *taking-off battens.* These are either of flat triangular section or of square section according to the taste of the loftsman (see Fig. 22).

To draw a Normal to a Curved Line.—A T-square shaped as in Fig. 22 is employed. The head is rounded terminating in two points which are equidistant from the drawing edge of the T-square. Therefore, by placing the square on a curved line the edge bisects and is normal to the chord joining the points where the head touches the curved line, and the line thus drawn is normal to the curve. The centre of curvature of the curved line will be in this normal.

Curved lines are drawn in by *penning battens* made of pitch pine and of rectangular section. These are of various sizes and lengths. There are three classes of penning battens, viz.

(i.) *Parallel* used for regular curves.

(ii.) *Tapered at one end* for curves of gradually increasing curvature.

(iii.) *Tapered in the middle* for curved lines which it is desired to draw in one length, but which are of sharp curvature in the middle portion. Such lines are the sections of a ship near midships which are usually sharp at the bilge.

Prepared discs of chalk, made of a compressed mixture of

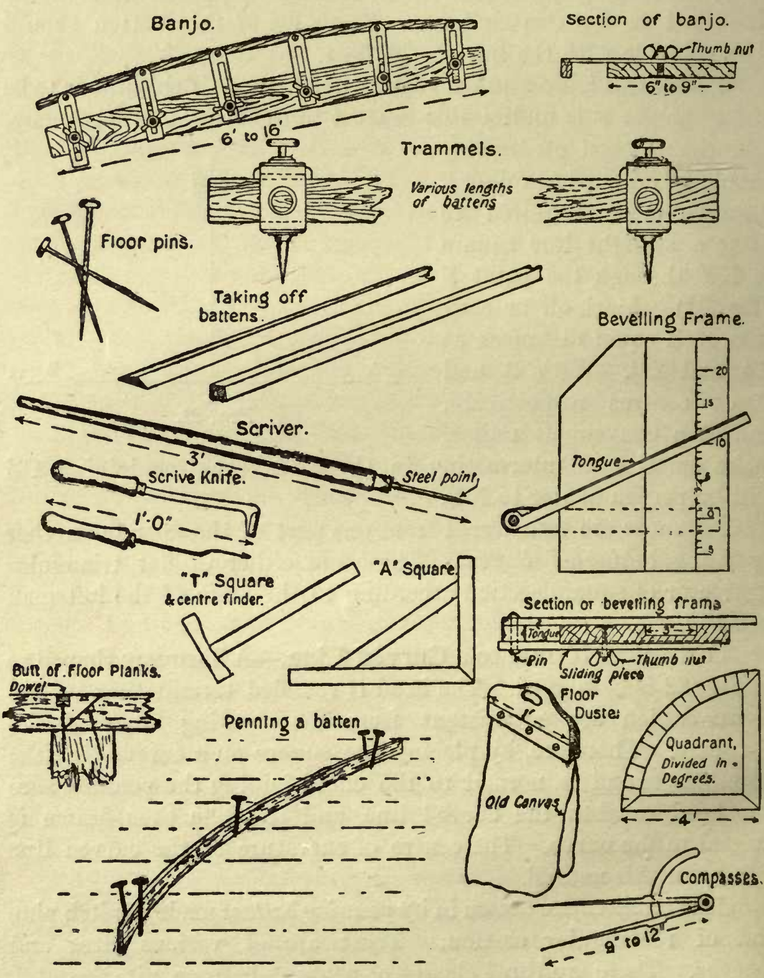


Fig. 22.

pipeclay, whiting, and plaster of Paris, and shaped with sharp edges, are used for marking on the floor the curves given by a batten. Some loftsmen prefer to use flat discs of French chalk. The battens are held in position to the required shape by means of floor pins nailed into the floor each side of the batten at convenient intervals. Some loftsmen use wooden mallets for driving the pins, but others use an ordinary claw hammer, the claw being used to pull the pins out. It is important to note when bending a batten that the fewest number of pins possible should be employed in order that the batten may take up an easy natural curve. When the curve is satisfactory, then extra pins may be added to stiffen the batten while running round it with the flat disc of chalk. The pins should be placed in pairs either side of the batten. It is always advisable to use the stiffest batten that will take the curve desired, as there is a better chance of fairness by this means. Also, as far as possible, the convex side of the batten should be the sighting edge for fairing and drawing in the curve.

Banjo.—For transferring a curve from one position to another a banjo frame is utilized (see Fig. 22). This is a flexible batten (of section, about $\frac{3}{4}$ in. by $\frac{3}{8}$ in. or 1 in. by $\frac{1}{2}$ in.), attached to a board by guides which are held in any required position by butterfly nuts. Banjos are made up to about 16 ft. long. The edges of the backboard are made hollow, straight, or round to deal with different classes of curved lines. The guides are about 9 in. or 1 ft. apart. When curves are too sharp to be transferred by a banjo they are traced on tracing paper and pricked through to the floor or on to the wooden mould it is desired to shape to the curve.

In some yards the body plan is scratched in on the floor for reference while the vessel is building, as the chalk lines get rubbed out and indistinct. In any case, it is usual to take off dimensions of the faired body and other portions and record them for future reference in a loft book. For the body plans placed on the scrive board, the surface of which receives rough treatment in the process of bending and setting the frames, etc., it is usual to *scrive* the lines in. This is done with a scrive knife, which is a piece of steel with a handle, as Fig. 22, the edge being turned over at the end and sharpened at the point. This actually cuts a groove out of the wood of the scrive board to the shape of the frames, etc., and the lines can then be readily picked out when required by running along with a piece of flat chalk.

Other accessories used on the floor which need no detailed description are shown in Fig. 22, viz. trammels (for drawing circular arcs of large radius), compasses with sharp points, A-squares, T-squares, prickers, rules, measuring staffs of convenient lengths, 5 ft. and upwards, steel tape, quadrant (for setting out angles), large drawing moulds of various shapes, and floor dusters. The bevelling frame will be described later.

There is an art in floor work which can only be learnt by actual experience. Accuracy is of the greatest importance; every measurement taken, and every line and curve drawn, should be done as carefully as possible. Errors have a disconcerting knack of multiplying, with results disastrous to accuracy. The loftsman should always have in mind the operations of the shipyard, and he should endeavour so to shape the various parts that the frame benders and platers can readily work to the same. A little thoughtfulness in this direction may save considerable trouble and expense in the subsequent operations at the ship.

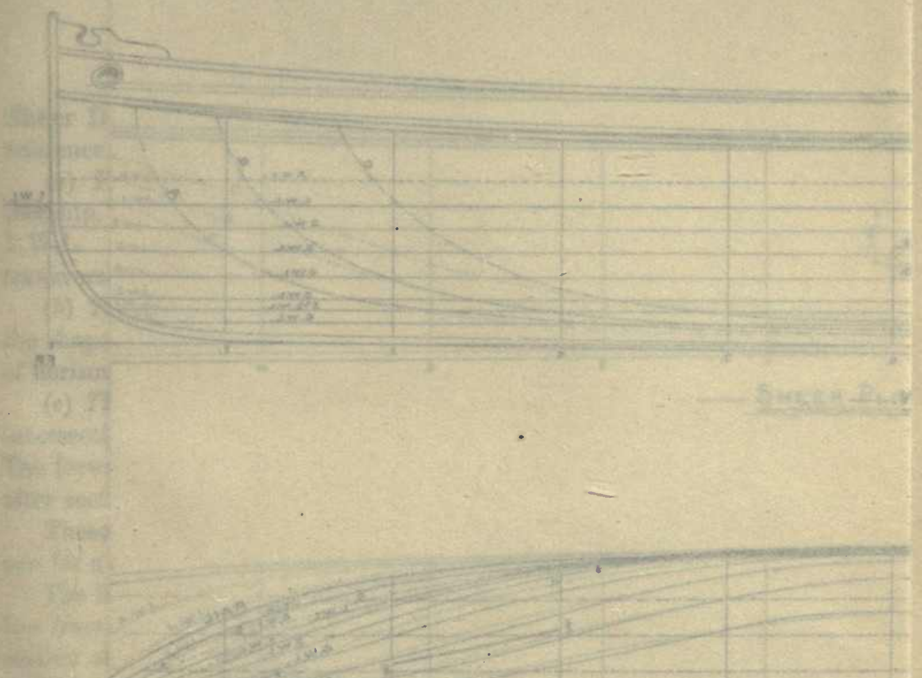
Associated with the mould loft, there are usually such machines as circular and band saws, and planing machines and also carpenters' benches, and trestles for supporting moulds. In an adjoining store there should be a stock of well-seasoned board and batten for the construction of moulds and templates.

Battens should be placed on a rack when not in use; when left lying about the floor the edges soon get damaged, and this results in bad work.

It may also be stated that every effort should be made to prevent persons not actually engaged on the work from walking across the floor, as the lines get obliterated in this way. In any case the entrance to the floor should be provided with a doormat, the use of which should be insisted upon.

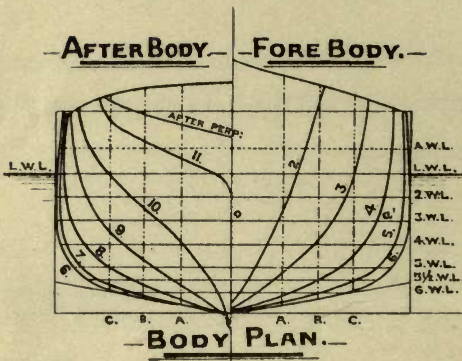
SHEER DRAWOUT AF

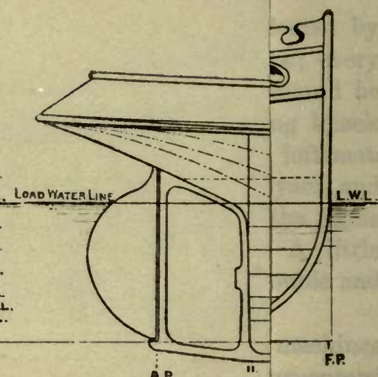
SCALE 1/8 - 1 FOOT



SHEER PLA

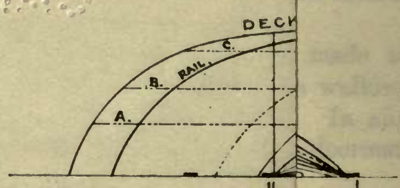
HALF BREADTH PLAN





PRINCIPAL DIMENSIONS

	FT.	INS.
LENGTH BETWEEN PERPENDICULARS	74	0
BREADTH MOULDED	14	6
DEPTH MOULDED	8	3
DRAUGHT MOULDED FORWARD	5	5
DO. DO. AFT	6	2
DO. DO. MEAN	5	9½



ge 19.

CHAPTER III

WORK ON THE MOULD LOFT FLOOR

Sheer Drawing.—To delineate the form of a ship three planes of reference are employed. These are—

(*a*) *The Sheer*, which gives the general outline of the profile of the ship, the position and sheer of decks, also the position of the L.W.L. Sometimes the main portions of the structure, as the transverse bulkheads, frames, vertical keel, decks, etc., are shown.

(*b*) *The Half-breadth*, which gives the shape of the decks and the shape of lines given by the intersection with the ship's surface of horizontal planes.

(*c*) *The Body Plan*, which gives the shape of lines given by the intersection with the ship's surface of transverse vertical planes. The forward sections constitute the *fore body* on the right and the after sections the *after body* on the left.

These three plans together form the sheer drawing, a specimen one for a small tug being given in Plate I.

The lines A, B, and C in the half-breadth and body are called *bow lines* forward and *buttock lines* aft, and the shape of the intersection of vertical planes through these lines with the surface of the ship appear as dotted in the sheer. (Although these lines are used in fairing the sheer drawing, they are not usually inked in in the finished plan.)

The three plans are mutually dependent; thus at No. 4 station the breadth at number 3 level line is given by *oa* in the half-breadth and also by *oa′* in the body plan, and these must be equal.

The bow and buttock lines must cross the level lines in the sheer at points which are squared up from the corresponding intersections in the half-breadth. They must also cross the sections at points which are squared across from the corresponding intersections in the body plan.

The work of designing the shape of a ship is a matter of "ship design." It will be sufficient here to say that displacement, fineness of form, shape of midship section, position of the centre of buoyancy, both fore and aft and vertically, and position of the transverse metacentre, all have to be considered. The process is often a matter of trial and error before a form having the desired qualities is obtained, and when obtained the form must be "fair," *i.e.* all the curved lines must run evenly and smoothly and the various portions of the sheer drawing must correspond as above described. The work of making a good sheer drawing can only be accomplished after much practice.

The student is strongly advised to draw out for himself at least one sheer drawing, and in the absence of a better example the drawing in Plate I. should be reproduced on a scale of, say, ½ in. to the foot. Enlarging to four times the size will magnify discrepancies, and it will be found an excellent exercise to produce a sheer drawing on this scale perfectly fair. In Plate I. the length from the after edge of stem to the fore edge of body post is 70 ft., and sections are employed 7 ft. apart. The level lines are 1 ft. apart except at the bottom, where they are 6 in. apart. The bow and buttock lines A, B, and C are respectively 2 ft., 3 ft. 6 in., and 5 ft. from the centre line. The rise of floor is 1 ft. 3 in. The semi-ordinates of the L.W.L. in feet commencing from forward are 0·05, 2·6, 4·9, 6·4, 7·0, 7·2, 7·1, 6·85, 6·3, 5·0, 0·65, and those for the water-lines at No. 6 section are 7·2, 7·25, 7·25, 7·1, 6·6, 5·95, 4·5.

The sheer drawing issued from the drawing office has now to be enlarged to full size on the floor. This drawing for a large ship will usually be drawn to the scale of ¼ in. to the foot. Measurements are sometimes sent out on a skeleton displacement sheet which define the shape of each displacement section and which will result in a form giving the desired qualities. It must be mentioned that the usual practice is to draw the sheer drawing to represent the "moulded" surface, *i.e.* to the frame lines, but for Admiralty work the drawing is to an imaginary line representing a mean thickness of plating added to the frame line, and this thickness must be allowed for when drawing in the frame lines on the floor. In the case of a sheer drawing for a "sheathed" ship the thickness of the planking as well as the plating must be allowed for. Methods of making these allowances will be discussed later.

In some yards the preliminary work of fairing is done with the displacement sections, and it is not until the body is approved as regards displacement, position of centre of buoyancy and metacentre, that the plating (or plank) is "taken off" and the moulded surface faired.

It is now a very usual practice in merchant shipyards to fair the ship on drawing paper stretched on a board, the drawing being made on a large scale (say ¾ in. to the foot for a large ship), and by skilful draughtsmanship exceedingly good results are obtained, the measurements from this drawing when completed being taken on diagonals direct to the scrive board. As a check on the fairness, it is desirable to transfer measurements on level lines and diagonals to the mould loft floor and have lines run through the spots thus obtained. The body plans which show each frame on this large scale are found of great assistance in the subsequent drawing office work, as exact drawings can be made, giving the shape of the ship at any desired position. *For Admiralty work it is usual to do the whole of the fairing on the mould loft floor.*

Length of Ship.—The length of the ship is usually defined as the "length between perpendiculars." The fore perpendicular (F.P.) is a line square to the designed load water-plane at its intersection with the fore edge of the stem (see Fig. 30). The after perpendicular (A.P.) is a line square to the designed water plane, usually through the centre line of the rudder head in war vessels. In merchant ships the A.P. is usually the after edge of the stern post, as in Plate I., and if the stern post has a rake, the point where the after edge produced meets the upper deck beam at centre, is taken as the A.P. For the F.P. if the stem has a rake the run of the fore edge of stem is continued up from below the water-line until it meets the upper deck beam at centre.

It is usual in merchant-ship practice to number displacement sections and frame stations from aft, but in Admiralty practice this is done from forward, except in some special cases. The number of displacement sections on the sheer drawing will vary with the size of ship. It is usual in Admiralty practice to use twenty-one ordinates, dividing the length between perpendiculars into twenty equal parts. The conditions will vary for different types of ships; thus the length for displacement in a single-screw merchant ship would be from the fore side of the body post to the after side of stern, and this length would be divided up as convenient for obtaining the displacement (see Plate I.).

Laying off on the Floor.—When transferring the measurements given on the skeleton displacement sheet or taken from the sheer drawing on to the floor full size, it is evident that inaccuracies which are not apparent on the small scale of the sheer drawing will be revealed, because of the great enlargement

(48 times for a $\frac{1}{4}$ in. scale drawing). The process by which a fair surface is obtained is called *fairing the body.*

Besides the sections, water-lines, and bow and buttock lines above mentioned, *diagonals* are freely employed for fairing the body. A diagonal is the shape of the intersection with the surface, of a plane which meets the middle line plane in a line parallel to the load water-plane, and which is inclined both to the sheer and the half-breadth. A diagonal will appear as a straight line in the body plan. Diagonals are of great use in fairing because we obtain with them square definite intersections with the sections. For instance, it will be noted in Plate I. that the intersections of the lower water-planes with the sections in the body plan are very acute and not easy to locate with perfect accuracy.

Rabatting is frequently employed, and the principle of this has been explained in Chap. I. When a plane is not parallel to one of the planes of projection (viz. sheer, half-breadth, or body) the true shape of the intersection is found by imagining the plane to be hinged about some axis which is parallel to one of the planes of projection, until the plane is itself parallel to that plane, when the true shape of the intersection will be determined. This process is termed *rabatting*, and the true shape is termed the *rabatment.*

The following is a simple instance of the process of rabatting.

To find the true shape of the intersection with the surface of a vessel of a diagonal plane inclined to the sheer and half-breadth and perpendicular to the body.—Such a plane is shown in the body by a straight line as AC (Fig. 23), and the projections

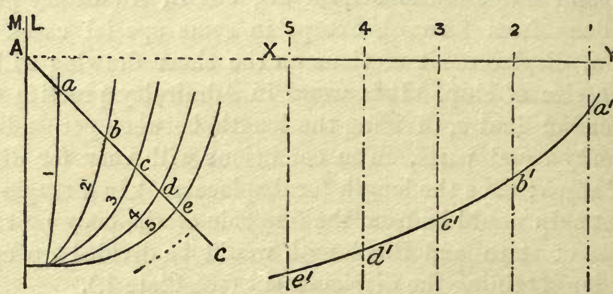


FIG. 23.

on the body plan of its intersections with the sections 1, 2, 3, etc., are *a*, *b*, *c*, . . . It is immaterial whether the plane is rabatted on to the sheer or the half-breadth. Take the former. Let XY be the axis of rabatment in the sheer, 1, 2, 3, etc., being the stations. Lay a batten along AC and mark off the positions of A, *a*, *b*, *c*, etc., and placing the batten successively on the sheer stations mark down from XY the points *a′*, *b′*, *c′*, etc., keeping the point A on the batten well with XY in each case. Then a curve through *a′b′c′*, etc., will be the true form of the diagonal intersection. It is seen that we have imagined the plane AC hinged down about a fore and aft axis through A. Rabatting on to the half-breadth is precisely similar.

The shape of a *cant frame, i.e.* a frame which lies in a vertical plane inclined to the sheer can be obtained in a similar manner.

More difficult examples are given later, as, for example, the *double cant*, which is a frame in a plane inclined to all the planes of projection.

Procedure on receipt of Drawings.—On receipt of the sheer draught and skeleton displacement sheet giving the ordinates, the floor is prepared for laying off. A base line is scrived in, choosing the middle of a plank if possible and watching to see that none of the level lines come at the intersection between two floor planks. At a convenient place a square line is horned in for the middle line of the body, and two side lines at the distance of the half-moulded extreme breadth each side of the middle line. The base line represents the level of the heel of frame amidships, which will be the thickness of the keel plating above the lowest point of the midship section. This base line serves as the datum line for the sheer and body plan and also as the centre line for the half breadth.

A batten is prepared, say 3 in. × $\frac{3}{4}$ in., with all the water-lines and level lines marked on in their relative positions and the base line also. This is used to mark these lines right along in preference to scaling, and is kept for reference throughout the job. If the ordinates given represent a mean thickness added to the frame line we take the ordinate given, and then from the spot on the level line strike in a circle having its radius equal to $1\frac{1}{2}$ times the thickness of the plating, as in Fig. 24. This done at all the spots will enable the frame lines to be run in by means of

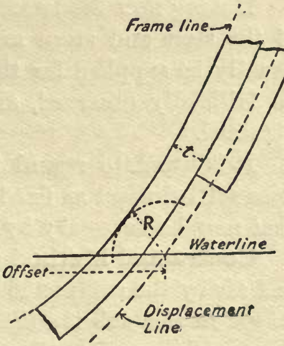


FIG. 24.

battens as tangents to these circles. (Taking off the plank will be described later; the above process is not sufficiently accurate in this case except at amidships, as the normal to the surface, of length equal to plank and plating, does not lie in the transverse plane.)

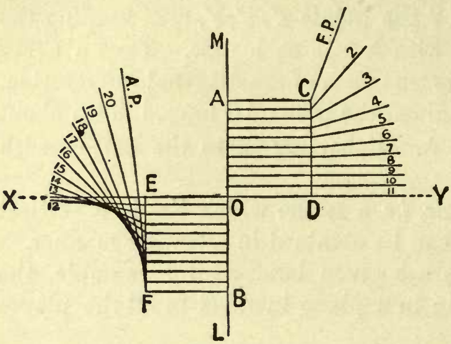


FIG. 25.

To end the Bottoms of the Ordinates.—It frequently happens that a ship in her designed condition as shown on the sheer *trims by the stern.* In such a case we proceed as follows, taking, for example, a trim by the stern of 2 ft. in the length between perpendiculars. Supposing there are twenty-one ordinates, we set up and down from the base line 1 ft. at A and B (Fig. 25), and we divide OA and OB each into ten divisions and strike in horizontal lines to meet the lines CD and EF, which represent the half siding of the keel from the middle line. The heels of the frames are then ended as shown. It will, of course, depend on the design whether the actual frames at the stem and stern will come down to these positions; usually this will not be the case.

Having now the twenty-one sections on the body, the contours of the stem and stern are drawn down full size. Drawings will usually be supplied for this purpose, and all measurements must be faithfully observed, always supposing that a pleasing line is obtained.

It is usual to regard the shape of the midship section when once settled upon as fixed and unalterable, and to do any fairing that may be necessary by altering other sections.

Contracted Method of Fairing.—It is usual to fair right fore and aft by the contracted method. This means that ordinates are struck in at a sub-multiple of the actual spacing (say one-third or one-fourth), see Fig. 26. This not only has the advantage of one being able to fair long portions of the ship at one time without any overlapping being necessary (as would be the case with the actual spacing of sections on account of the limited length of floor), but it has the great advantage of rendering the curves sharper and the battens are more likely to give a fair line because of the greater curvature to which they are bent. It is very difficult to make a long flat curve perfectly fair. In the bluff vessels formerly built it was only the midship portions that could be faired by this contracted method, but in the majority of vessels now built the contracted curves can be run practically the whole length, as the

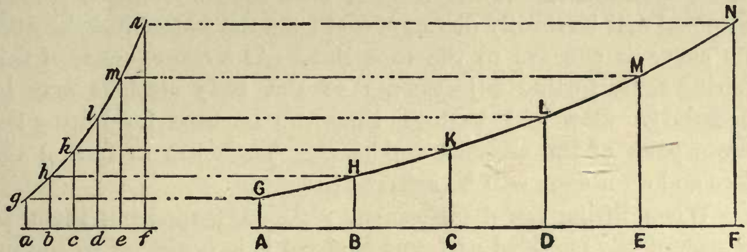


FIG. 26.

intersections with the ordinates are not so acute as to render the location of the exact crossing a matter of difficulty. It is necessary to fair the extreme ends of the ship *full size*, as the sections of the stem and stern-post have to be determined. To ensure continuity it is usual to overlap for a distance of about two section spaces, sometimes three at the after end.

The scale of contraction is influenced by the spacing of the frames: if possible a figure should be used so that no awkward fraction of an inch is obtained between the frames when they are set out on the contracted scale.

To fair a Water-line.—Lay a taking-off batten along the water-line in the body plan and mark on it the middle line and the intersection of each section, then turn the batten end for end and do the other side. Using the middle line spot as a pitch mark, set off on the respective ordinates in the contracted half-breadth. Through the spots thus obtained bend a long batten, keeping the midship section spot well, and get in a fair line, taking as many of the spots as possible. All the level lines are run in in this manner, and the new intersections are transferred to the body. New sections are run in as nearly as possible through these new spots, always taking care to have fair lines. This process is repeated between the body plan and the half-breadth until all the lines are fair and are in perfect agreement. One gets a sort of instinct after practice in this process of fairing. For instance, if on the half-breadth the fair line comes outside the spot, one knows that the section must be filled out some distance above and below, and the other water-lines at this section must also be filled out in sympathy.

As a further test of fairness we next lay off diagonals. These are struck in as nearly normal to the frame lines as possible. It is well to make a point outside the midship section, the axis of rabatment (the intersection with the half-breadth line or base line being convenient). When rabatted from such an outside point a diagonal will be readily distinguished from the water-lines, because its curve is concave to the base line. As a consequence of this fairing some further adjustments of the body sections may be necessary. Bow and buttock lines can be used for fairing the lower parts of the sections amidships. Their use in fairing the fore and after ends will be referred to later.

When lifting the displacement sections (supposing them to represent the moulded or frame surface) it is necessary to add on the thickness of plating formerly taken off in order that the displacement may be calculated. This is done by the following method. A small set-square is made, XYZ (Fig. 27), the length of YZ being $1\frac{1}{2}$ times the thickness of the plating. The tape is stretched along the water-line, PQ being a section, and the set-square is placed as shown, the edge YX being placed as a tangent to the section, and the point Z being on the tape measure. The dimension at Z is then read off. If an ordinary scale is employed, the inches must be turned into decimals of a foot, but preferably a decimally divided tape measure is employed. In Fig. 27 the dimension to be transferred to the displacement sheet is 19·14 ft., the nearest second place of decimals being sufficiently accurate.

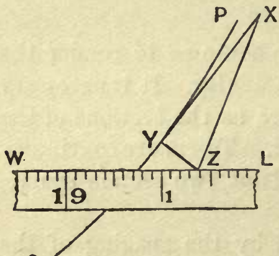


Fig. 27.

The fairing of the ship above the load water-line presents no difficulty, level lines being used immediately below the decks and at suitable places between.

When the body plan as faired is approved, *each frame* can be lifted from the contracted water-lines, diagonals, etc, and transferred to the body plan. The position of each of the frames are set out on the contracted scale in correct relative positions to the displacement ordinates. The battens on which the points are marked are carefully numbered for identification, and are afterwards used for transferring the body to the scrive board in the yard near to the frame-bending slab. (In some yards the scrive board is prepared in the mould loft and dismantled to be taken into the yard.)

In ending the frame lines in the body some care has to be taken at the lower parts owing to the variation of the keel plate thickness. The "lifting" at the stations do not appear at regular intervals on the body plan. A "lifting batten" is prepared as described on page 91. On the M.L. of body plan, Fig. 28, set off

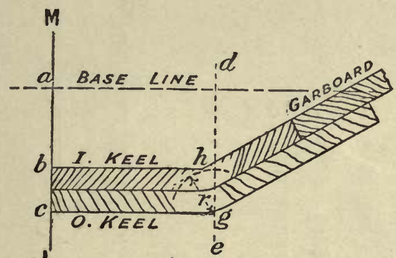


Fig. 28.

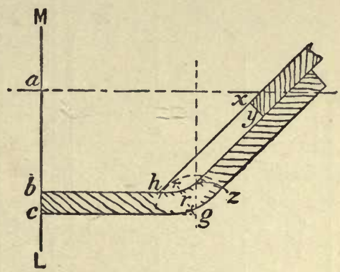


Fig. 29.

ab, the "frame lifting" in relation to the base line, and *ac* the underside of keel, also *de* the half siding of outer keel. With centre *g* and radius *r* equal to *bc* draw a circular arc. The frame line is finished as a tangent to this arc, meeting the line of "frame lifting" at *h*.

In the case of the forward and after ends where the flat keel is in one thickness, the distance *bc,* Fig. 29, is equal only to the thickness of the keel plate. The circular arc drawn from centre *g* has a radius equal to the combined thicknesses of the keel and garboard. This allows for a parallel liner filling the space *xyzh.*

Fairing the Fore End.—This has to be done full size, and each frame station is employed. The frame stations are lifted from the contracted half-breadth and lines run in, say up to No. 3 ordinate, with the stations placed their proper distance apart and in correct relation to the contour of the stem and the F.P. The water-lines have to be ended properly at the stem, regard being had to the thickness of the stem desired, which will be indicated on the stem drawing.

The fore end of each water-line is ended as follows (see Fig. 30, in which the sheer and half-breadth are separated for clearness). The fore edge of stem as at a' at each water-line is squared down to the middle line of half-breadth as at a_0. An imaginary half-siding of stem is employed, as in Fig. 30 (a), where the frame line produced would meet the square line through A_0 in the point A. A_0A is this "frame half-siding." The widths such as A_0A must be determined

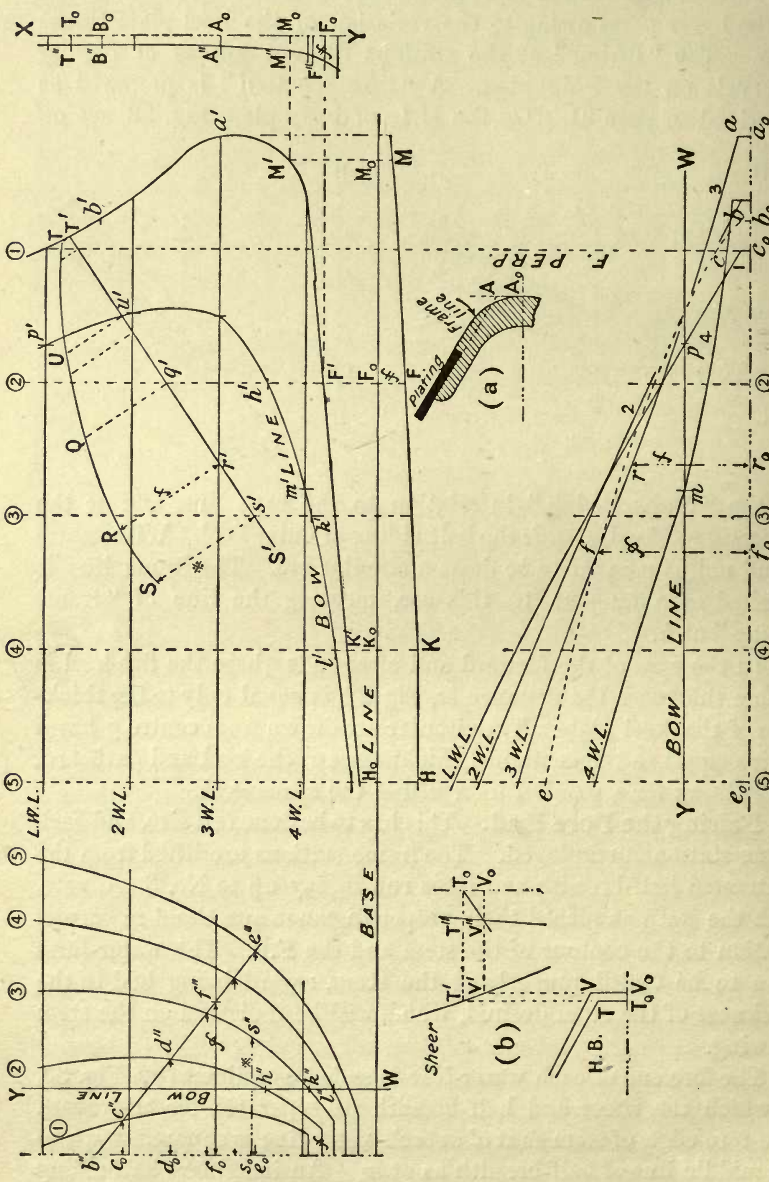


FIG. 30.

(NOTE.—The arrow mark in figure (a) should extend to the dotted line.)

by the requirements of the siding of the finished stem as shown on the stem drawing. It is necessary to fair such points as A. A line XY is drawn parallel to the fore perpendicular, and breadths set out at the different levels to correspond to the frame half-siding required. A fair line must be made to run as evenly as possible through these spots as shown. Below the lowest water-line we proceed as follows: Below the base line set out H_0H for the frame half-siding of keel (*i.e.* *bh* in Fig. 29), which will usually be parallel up to some point as K_0. Square down points as F′ on the fore edge of the stem, making F_0F equal to F_0F''. We then fair a line through K and such points as F. Spots can then be lifted from this line and transferred to the corresponding places on the half-siding of stem curve; thus, M_0M'' is equal to M_0M, both corresponding to the point M′ on the stem; the whole curve through such spots as M″ can then be faired in, and the frame half-siding of stem can be lifted at any desired height. The frames in the body will also be drawn to end at the half-siding, as measured from KFM, at the proper height as given by the stem contour. This, again, will be an imaginary half-siding in way of the stem casting, used to determine the run of the frame line.

Some loftsmen further test the fairness by using *horizontal ribband lines.* Let $b''e''$ be a diagonal in the body plan (Fig. 30). Measure the *horizontal* distances of the intersections c'', d'', etc., from the centre line on a batten and transfer to the half-breadth from which the dotted curve *efc* is obtained. The breadth f_0f in half-breadth where the dotted curve crosses No. 3 W.L. must be equal to the distance of the intersection of the diagonal and No. 3 W.L. in the body from the centre line, *i.e.* f_0f'', and so on for each position where $b''e''$ crosses a water-line. *This is a very searching test of fairness.* To end the dotted line in the half-breadth, square b'' across from the body to the stem in the sheer at b' and find the frame half-siding B_0B'' at that height. Square b' down to the half-breadth at b_0, and make b_0b equal to B_0B. The dotted curve will end at *b*.

The above ending of the horizontal ribband is not strictly correct, although sufficiently so for all practical purposes. The following gives a correct method. T′ on the stem contour (Fig. 30 (b)) being projected to T_0, T_0V'' is drawn, making the angle $V''T_0V_0$ equal to the angle $e_0b''e''$, the inclination of the diagonal to the middle line plane. V″ is then projected to the stem at V′, and V′ is projected down to the half-breadth and V_0V made equal to V_0V''; the line is then ended at the point V.

The final test of fairing with *bow lines* is now employed. Let YW be a bow line in the body and half-breadth. Transfer the intersections with the sections in the body to the sheer at h', k', etc., and also the intersections with the water-lines in the half-breadth are transferred up to the sheer, as m to m', p to p', etc. Fair a curve through as many spots as possible.

In connection with this fairing a very interesting point occurs. In ordinary fairing, to quote an old loftman's dictum, "midway between is right to both," but this will not apply to bow or buttock lines. In Fig. 31 let BB be a bow line and a', b', c' spots projected from the body, and p', q', r' spots projected from the

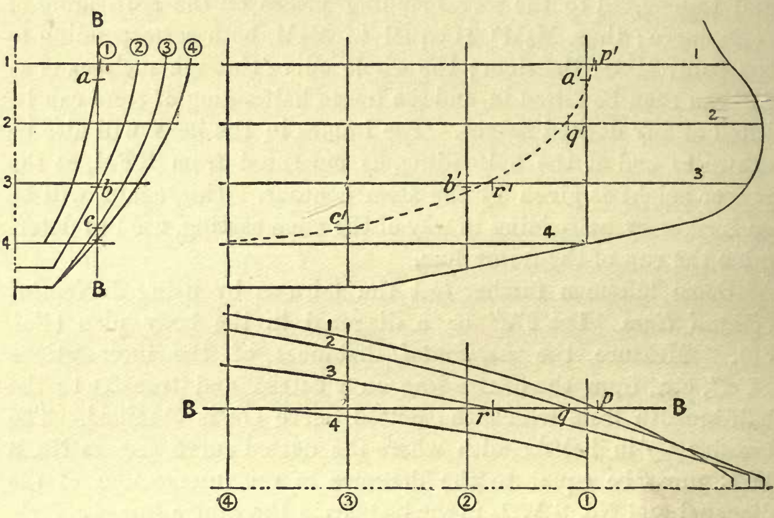


FIG. 31.

half-breadth. There is evidently unfairness. If a curve as dotted is passed between b' and r' this will have the effect of pulling the frame down, which in turn will fill out the water-line and the point r' will go further forward still, but r' appears to want to go aft. There is thus direct opposition, and agreement is not possible, unless we go ***right outside*** or ***right inside*** both spots, so that the section and water-line are both filled out or both made finer. In this way an agreement can be reached. Whether we go outside or inside must depend on the requirements at the adjacent water-lines.

The frame liftings at the point of cut-up will rise suddenly and appear on the body plan as Fig. 32. If the half-siding is kept the same all the way up, then unfairness of the sections will result, as shown by the dotted lines. A bow line, DE, should be put in close to the half-siding line and faired. The half-siding line above the cut-up will then take the form *a′b′c′*.

The after end of the vessel is faired in a similar manner.

Fairing a Stem Casting.—The stem in merchant vessels and in the smaller classes of war vessel is usually formed of a flat bar, but in war vessels above about 3000 tons displacement the stem is formed of a steel casting, into which the bottom plating is rabbeted. In some cases armour or thick protective plating has to be recessed into the stem casting. Formerly in large war vessels the stem was made very massive in order to form a "ram" (see Attwood's "Warships" for examples); but in vessels now building the stem casting is of more moderate dimensions, and is for the purpose of obtaining an efficient ending to the fore end of the ship.

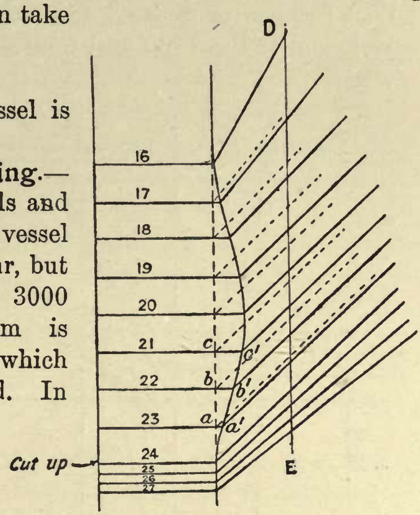


FIG. 32.

With a cast-steel stem it is necessary to prepare all the information for the use of the pattern maker in making the pattern. This consists of a mould showing the contour of the stem, which section moulds about 3 ft. apart, giving the shape of sections normal to the contour. The stem drawing will indicate the various dimensions to be worked to, thickness of metal, webs for connecting to decks, frames, vertical keel, etc.

The frame line for each water-line will already, as described above, be run in to an assumed half-siding (MN, Fig. 33 (b)). A spot, X, is marked in for the after end of the casting, XY is the breadth of the rabbet, and YZ the thickness of shell plating, protective plating or armour, as may be necessary. RZK is drawn parallel to XYN, and the stem section must fair into this, usually with a circular arc with centre on the middle line. The inside of the stem PWV is also drawn in as required to give the proper thickness. This being done for several water-lines and the sections treated similarly, spots as X and Y are squared to the middle line, giving points as B and E. These points, and points as P, are faired on the sheer, giving curves for the "back edge," "centre of rabbet," and "thickness line." The lugs for attachment to the decks and frames are then added.

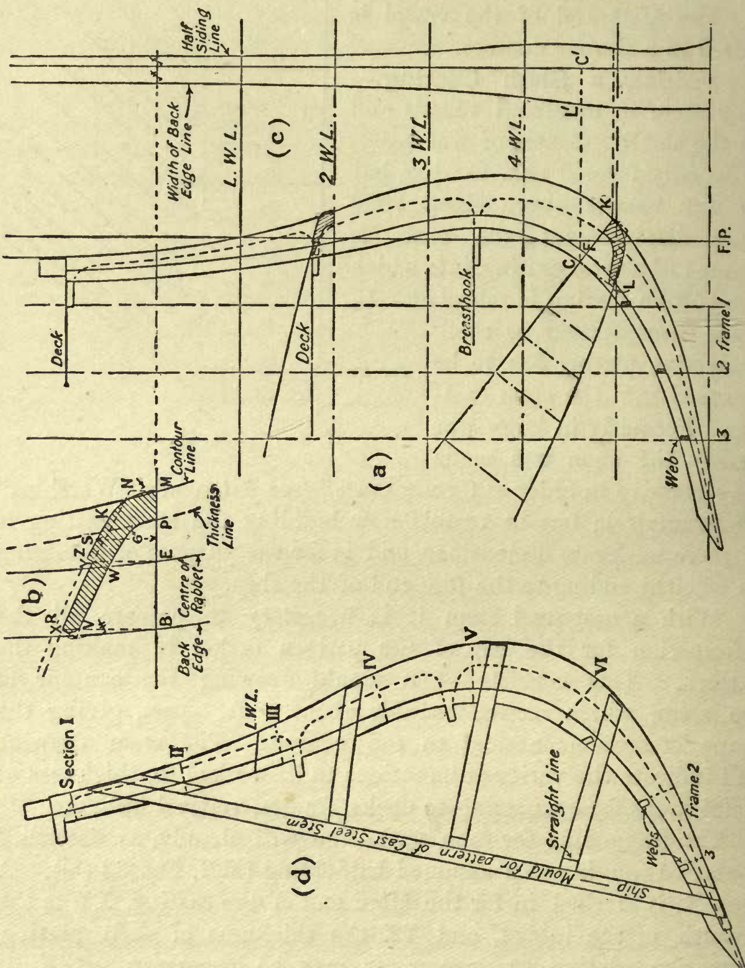


FIG. 33.

Breadths, as BX and MN, are faired as shown on the right of the figure; also a bow line is run in about 3 to 6 in. from the middle line for fairing such points as S (Fig. 33 (b)).

The sections for the pattern maker are made at the L.W.L., and at sections normal to the contour, and at the frames. For the normal sections we obtain the shape of the intersection of a normal plane by rabatting on to the sheer as at KC, Fig. 33.

Let T′S′, Fig. 30, be such a section normal to the contour at T′. This crosses the frames in points as q' and s', water-lines in points as r', and bow lines in points as u'. Rabat about S′T′ on to the sheer, drawing normals at these various intersections. On each, set off the breadth of the ship. Thus, s'S equals s_0s'' from the body, r'R equals r_0r from the half-breadth, and u'U equals the distance of the bow line from the middle line. The breadth at the ending, viz. T′T, equals T_0T'' from the half-siding line at the side. The curve through SR . . . UT will be the shape of the diagonal section, and this will determine the shape of the stem at the point T′ normal to the contour. The section can then be built up as shown at CK in Fig. 33 (a) by squaring out from C and K, making CL = C′L′, etc.

Fairing the Inner Bottom.—After the outer bottom frame lines are fixed on the floor, the longitudinals have to be arranged and the frame lines of the inner bottom faired.

The sight edges of the longitudinals will, by this time, have

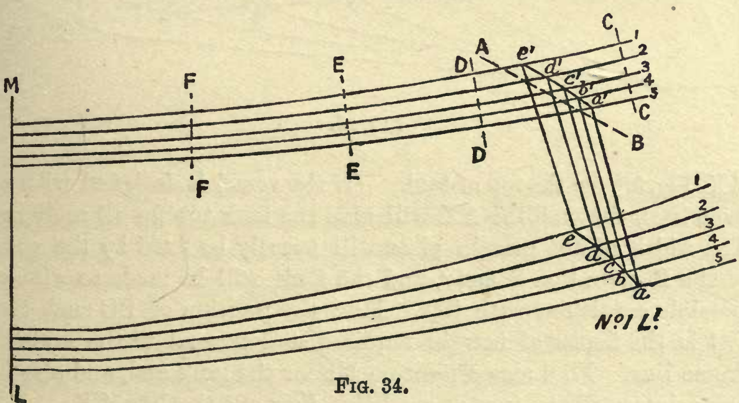


FIG. 34.

been faired on the half-block model. The sight edges are transferred to the floor by girthing the frames on the model from the middle line, and fair lines are scrived in for the outer sight edges as *abcde*, Fig. 34.

The traces of a longitudinal on the sections in the body plan are straight lines through the points *a*, *b*, etc., and these are usually normal to the frame line, unless some special local condition has to be satisfied, as, *e.g.* turning to pick up the girders of engine and boiler bearers on top of inner bottom, or twisting into a flat or a fore and aft bulkhead.

The traces are first roughly faired by laying off a diagonal AB, placed in the vicinity of the inner bottom. On the traces the depths of the several longitudinals are set up, and the inner bottom lines are put through these spots, these being further faired by means of diagonals, as CC, etc. The top edge of each longitudinal is now made quite fair as at $a'b'c'$, etc., and the final traces aa', bb', etc., are scrived in.

In merchant vessels the cellular tank takes the place of the double bottom. The top of this tank is usually level or sloping down slightly from the middle line, and the tank margin plate forms the outer boundary. To fair the margin plate, first get in a line

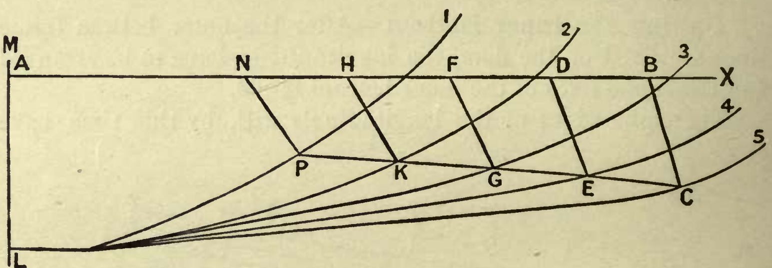


Fig. 35.

AX, Fig. 35, for the top of tank. (If the vessel is designed with an even keel, the one line AX will give the tank top for all sections.) The width of the margin plate will usually be fixed by the rules of the Registration Society, and the tank will be made as wide as possible consistent with this. Find the position of BC such that BC is the depth of margin required, and normal to the midship frame line. Find also a position NP for the tank end, and also for some intermediate frames as FG. Fair up the line CE . . . P in the body plan, and draw in the traces of the margin plate. The top and bottom edges are then faired in plan, and the final positions of the traces DE, FG, etc., are drawn in. The traces on other intermediate stations can be obtained from the fairing lines.

The method of development of the margin plate is similar to that of a longitudinal (given later). The fore and aft girders between the margin plate and centre keel are usually vertical, and their development presents no difficulty.

The Bevelling Frame.—This is shown in Fig. 22, Chap. II., and consists of a backboard and a hinged tongue. The scale marked on is usually one-quarter full size, and the tongue can slide along and be secured by the thumb nut beneath so as to be adjustable for different frame spacings, this being also arranged for one-quarter full size. Such a frame can be employed for obtaining the bevels of any bar directly from the projections of its edges in the body plan.

Suppose 1 and 2, Fig. 36, represent two frame stations on the body plan, and it is required to find the bevel of frame bar No. 1 at the point A, the flange of the bar looking towards No. 2.

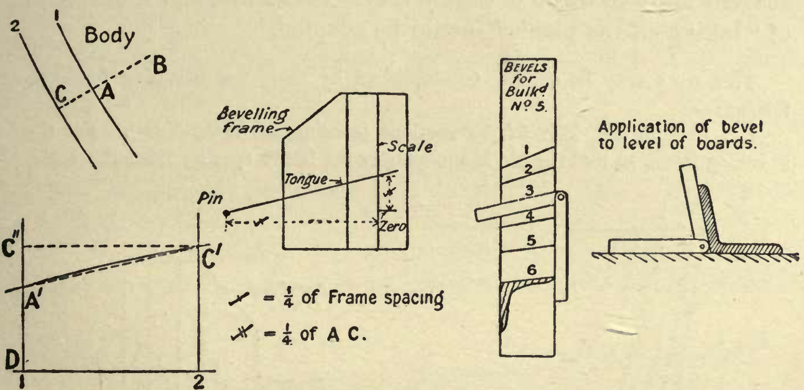


FIG. 36.

Bevels should always apply square to the moulding edge. Therefore draw CAB square to station 1 at A. This diagonal will be represented by the line A′C′ in the half-breadth, and the bevel of the bar at A is not appreciably different from the angle DA′C′. Square C′C″ across; then the distance A′C″ will be the same as AC in the body. The bevelling frame enables us to determine a triangle similar to A′C′C″, and hence the bevel of the frame, DA′C′.

Procedure.—Set the distance of the pin from the scale at one-quarter the frame spacing; the zero of the scale is in line with the centre of the pin (Fig. 22). The hinged tongue is then turned until the edge passes through the point on the scale representing one-quarter the distance AC as measured from the floor, perpendicular to the frame line No. 1 at the point A. The triangle AC′C″ is thus represented, and the bevel is marked across a narrow parallel board slipped under the tongue in the groove provided in the bevelling board (Fig. 22 and Fig. 36). The bevel taken off the board must be such that it can be applied to the back of the bar as shown in Fig. 36. Any other bevels required may be obtained in a similar manner, as *e.g.* the bevel of angles connecting frames to longitudinals.

Frame Lines behind Armour.—The armour plating on the sides of a warship is fitted in a recess, and the outer bottom plating of the ship behind armour is set back sufficiently far to allow of the backing and armour to be fitted. This can readily be done on the body for the midship portion. At the ends, account must be taken of the curvatur both ways, and the method of "taking off the plank" should be adopted.

This work may be quickly accomplished by using the bevelling frame as follows:—

Let 1, 2, 3, etc., Fig. 37, be sections (continuous frame lines). Set the bevelling frame so that the pin is one-quarter the frame spacing from the scale.

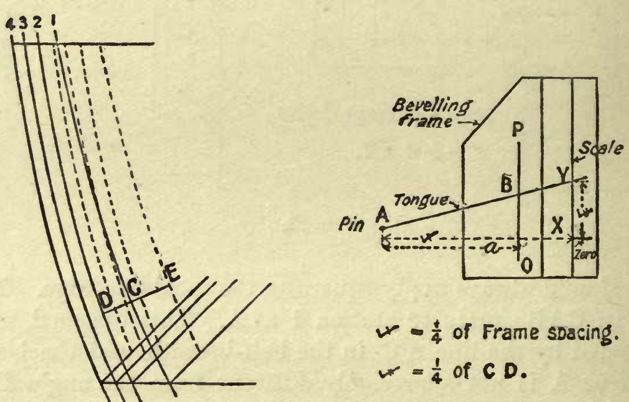


FIG. 37.

Mark on the backboard of the bevelling frame a line PQ so that the distance *a* equals one-quarter the thickness of plating, backing, and armour minus the thickness of outer bottom plating. Set the tongue of the board so that XY represents CD; then the distance AB must be set back to E in the body square to the frame line at C. This being done for several spots, the framing behind armour can be got in as shown dotted.

Beam Curve.—Beams are usually given a "round-up" and the curve is made to the arc of a circle. This gives a slope to clear the deck of water. The amount of round-up in merchant vessels is laid down to be ¼ in. in each foot of breadth, and this standard is assumed in settling the freeboard as it slightly increases the "reserve of buoyancy," *i.e.* the watertight volume above the water-line. There is no fixed rule for the round-up

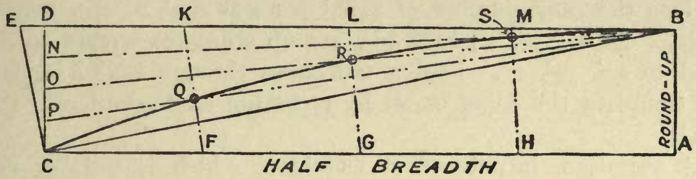


FIG. 38.

in war vessels; the following are examples, viz. 6 in. in 39 ft., 9 in. in 75 ft., 15 in. in 90 ft.

The following construction may be used for obtaining the beam curve and results in a circular arc (see Fig. 38). AC is the half-breadth at which the round-up is AB. Complete the rectangle ABDC, and drawing the diagonal BC draw CE perpendicular to it meeting BD produced in E. Divide AC and BE into the same number of equal parts, say 4, and join corresponding

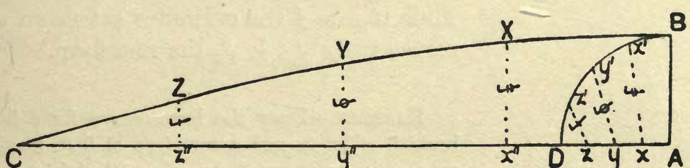


Fig. 38A.

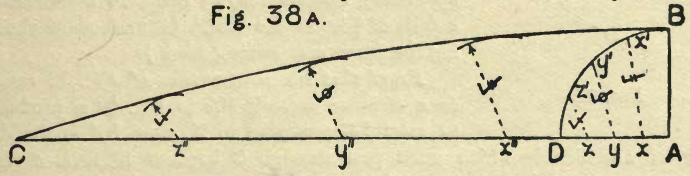


Fig. 38B.

points as FK, etc. Divide C D also into 4 at the points P, O, and N, and join these points to B. Then the points Q, R, and S with B and C, lie on a fair curve which is a circular arc. This curve is the beam curve to which a mould is made for the full breadth. There are other methods of obtaining a beam curve, but the above is as good as any.

In practice, it is almost invariably the rule to use an approximate method as one of the following:—

In Figs. 38A and 38B, let AB be the amount of round of beam, and AC the half full breadth of the vessel. With centre A and radius AB describe the arc BD. Divide AD, the arc BD, and AC into the same number of equal parts at x, x', x'', etc., respectively. At x'', y'', z'', Fig. 38A, set up ordinates square to AC equal to xx', yy', zz'. Pass a fair curve through BXYZ and C, and complete the beam curve by repeating on the opposite side of AB.

A variation, introduced at Chatham, which is quicker and gives practically the same result, is shown in Fig. 38B. In this case arcs of circles with centres x'', y'', z'', and radii equal to xx', yy', zz' respectively, are drawn in and the curve passes through B and C and touches the arcs.

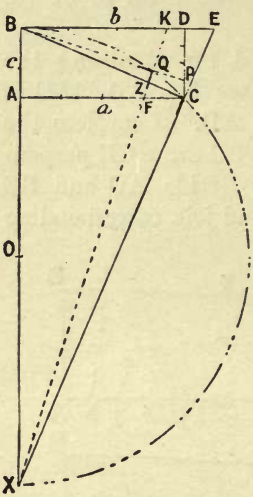


FIG. 39.

The following is a simple method. Divide the half-breadth into n equal parts and set down respectively $\left(\frac{1}{n}\right)^2$ $\left(\frac{2}{n}\right)^2$ etc., of the round-up. This results in a parabola which is practically a circular arc. Thus if $n = 4$ the ordinates set down are respectively $\frac{1}{16}$, $\frac{1}{4}$, $\frac{9}{16}$ the round-up.

EXAMPLE.—Draw the beam curve for a half-breadth of 30 ft. and a round-up of 5 ft. (round-up greatly exaggerated) by using 10 divisions, on a scale of $\frac{1}{4}$ in. to the foot. (A method of checking the curve may suggest itself.)

Proof that the construction of Fig. 38 *results in a circular arc.*—If BA in Fig. 39 is produced to meet EC produced in X, then BX is the diameter of a semicircle which must pass through C because BCX is a right angle.

The proof that this semicircle will also pass through such points as Q consists of two parts, viz.—

(i.) That KF produced passes through X; and
(ii.) That $\angle$ BQX is a right angle.

For (i.) we have that BK : KE = AF : FC, which by the properties of triangles necessitates KF produced passing through X.

For (ii.) we now proceed to prove that BQZ and XCZ are similar triangles, and therefore $\angle$ BQZ = $\angle$ XCZ = a right angle.

The triangles CAB and XBC are similar because $\angle$ XBC is common and $\angle$ BAC = BCX, viz. a right angle.

$$\therefore \frac{CA}{AB} = \frac{CX}{CB} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (1)$$

Also by construction

$$\frac{CF}{CA} = \frac{CP}{CD} = \frac{CP}{BA}, \text{ from which } \frac{CA}{BA} = \frac{CF}{CP}$$

Hence by (1) $$\frac{CX}{CB} = \frac{CF}{CP} \text{ or } \frac{CX}{CF} = \frac{CB}{CP}$$

and since $\angle$ PCB = $\angle$ ACX, the triangles CPB, XCF are similar, and $\angle$ PBC = $\angle$ FXC.

Therefore in the triangles BQZ, XCZ there are two angles equal respectively in each, viz. $\angle$ QBZ = $\angle$ ZXC and $\angle$ BZQ = $\angle$ XZC, therefore the remaining angles are equal, viz. $\angle$ BQZ and $\angle$ XCZ, which latter is a right angle by construction.

The following is the proof by using the methods of analytical geometry:—

Let AC = a, BE = b, and AB = c (Fig. 39).

Then BK = some sub-multiple of BE = $n . b$ say,
and AF will equal $n . a$ and DP = $n . c$

Referring to axes BE and BA as axes of x and y respectively, then the equation to BP is $y = n . \frac{c}{a} . x$, and the equation to KF is $y = \frac{c}{n(a-b)} . x - \frac{b . c}{a - b}$.

Eliminating n from these equations will give the locus of all such points as Q, viz.—

$$c^2 . x^2 + c^2 . y^2 - a . b . c . y = 0$$

which is the equation to a circle passing through B and C with axes BE and BA.

Sheer.—Nearly all vessels have the forward and after ends of weather decks raised above the midship level, partly for appearance sake and also that the ship may be kept dry, especially at the forward end. The amount of the sheer and the line of the sheer are shown on the sheer drawing for war vessels. For merchant vessels the amount of sheer is reckoned in when settling the freeboard, and the rules of the Board of Trade define the requirements for the sheer line.

In either case the sheer *at the centre line* is faired on the contracted sections, care being taken to maintain any figured heights given on the sheer drawing.

A batten is prepared having a pitch mark on the L.W.L., and on it are lifted the positions of the beam at middle spots for each frame. All deck sheers or levels are marked on the same batten.

The beam round curve is put on the body plan for the full breadth of the vessel, so that the highest point of the camber is at the height of the beam at middle of the amidship beam.

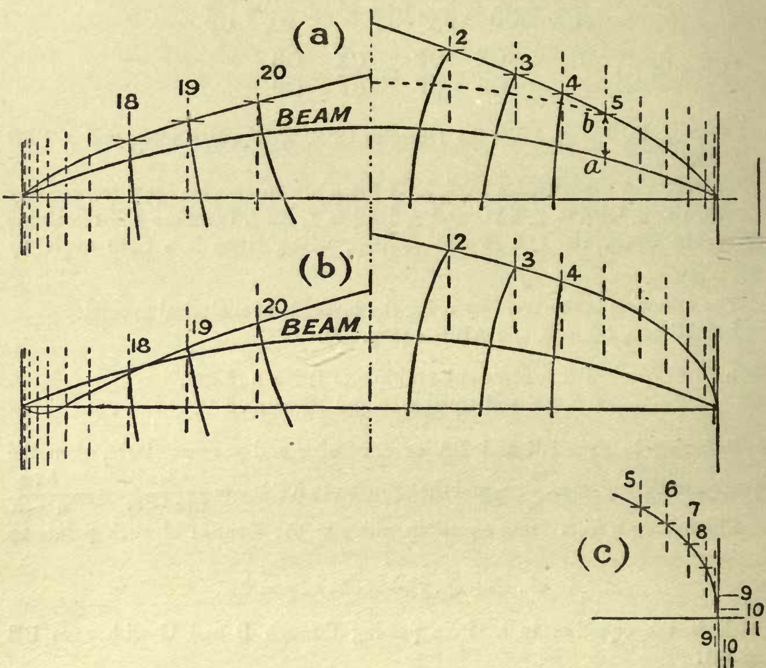


Fig. 40.

To get in the Beam at Side Line.[1]—A plan of the deck at side is copied and faired in the contracted half-breadth, and the half-breadth at each frame is lifted. Immediately above and below the beam at side line in the body plan these breadths are marked off from the M.L. and short vertical lines are snapped in for each station. The frames will end somewhere on these lines. Mark off on the M.L. the heights of the deck at centre at each frame. We now have to determine just how far below the beam at middle each spot in the beam at side comes. We have virtually to place the beam round mould successively at each beam at middle spot, place it parallel to the L.W.L., and then determine its intersection

[1] Sometimes called the Beam End Line.

with the short vertical lines giving the half-breadths. Actually to do this would be too laborious; the following method is adopted.

Take off on a batten each beam at middle spot, using the amidship spot as a pitch mark. Then, keeping this mark well with the midship beam line, set up on each perpendicular line the corresponding height of beam at middle above the midship beam, as *ab* at station 5, Fig. 40 (a). It will be seen that spots thus obtained are spots for the beam at side in the body. A curve is faired through these spots and taken to the contracted sheer, adjusted as necessary, and taken back again.

When the lowest point of the sheer is not amidships the beam at side comes below the midship beam, as in Fig. 40 (b). Also if the vessel is very flat for the midship portion of the length, the beam at side curve becomes so steep that intersections with the frame lines become indeterminate. In this case the height of the beam at side for each frame is scrived in at the side parallel to the L.W.L. as in Fig. 40 (c).

Taking off the Plank.—With a sheathed or composite ship the sheer drawing is drawn to the outside surface, and it is necessary in order to obtain the moulded surface to "take off the plank." Forward and aft of amidships a normal to the ship's surface will generally not lie either in a level or a transverse plane. To take off the plank accurately is a problem of some difficulty, and this is given later. The following approximate method is found to be sufficiently accurate. Let a water-line and section be as in Fig. 41. Square in from the run of the water-line the distance *bc* equal to the thickness of plank and plating. Take *ac* to the body and square in to the run of the section to obtain the point *e*′. Then the line through all such points as *e*′ will give approximately the "moulded" section, and from a number of sections the "moulded" water-line as dotted can be obtained.

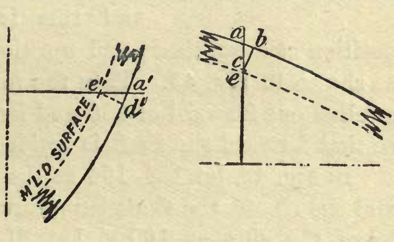


FIG. 41.

Exact Method of taking off the Plank.—In Fig. 42 three level lines are shown at *ac*, *df*, *gk* in plan and the middle section *b′e′h′* in the body. The half-breadth has been turned round to come beneath the body for the sake of clearness.

Take a point as e and draw el normal to the level line def in plan, meeting the middle line in l, and draw $e'l'$ normal to the section at e', meeting the middle line in l'. Then the line (el, $e'l'$) is the normal to the ship's surface at the point (e, e'). Rabat this line on to the half-breadth about el, making lL perpendicular to el and equal to l_0l', and joining Le. Then Le is the true length of the perpendicular to the ship's surface at (e, e') to where it cuts the middle line plane. Set off eM equal to the thickness of plank (and plating if any). If now through M a line is drawn parallel to the section at e' meeting el in m, then m will be in the level plane a distance away from the surface equal to the thickness of the plank. Now draw mo parallel to the level line at e, cutting the section in o. Then o is a point in the level at the section beh. Square o up to the sheer at o'. Similar points p' and q' are obtained for other level lines. Then lines as $p'o'q'$ will be the required section lines for inside of plank. Similar lines can be drawn in the half-breadth.

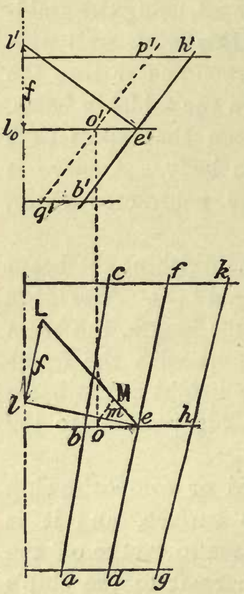


FIG. 42.

Fairing the Shaft Swell.—It is usual in war vessels to support the after end of shafting by means of brackets, and the after portion of the shafting revolves freely in the water. It is necessary to make a special construction where the shaft leaves the ship, and this is usually done by fixing this position at a bulkhead and working a casting to take the bearing as shown in Fig. 43. Thus the form of the ship must be locally swelled out forward of 160 and locally recessed aft of this station, so that forward the shaft is inside the ship and abaft it is outside.

In Fig. 43, let 154–164 be the frame lines in way of the boss and the recess, the shaft being arranged in the design drawings to leave the ship at 160. Let SL be a line drawn through the centres of shaft, which is seen to incline both to the sheer and the half-breadth. Draw a diagonal plane through the centre of shaft about normal to the frame lines; this will be indicated by its traces with the plane of each frame shown dotted in the body. A straight line XY is drawn perpendicular to these traces. In the half-breadth X'Y' is drawn to represent the line XY, and by measuring along the traces from XY to (1) each frame, and (2) the centre of shaft, we obtain the lines shown in half-breadth, viz. HMN and S'L' (the expansion due to the run down of the shaft is ignored).

The amount of swell at 160 is settled according to the particular design adopted, and the distance CA is set off from the centre of shaft. AB is drawn parallel to the centre of shaft; the

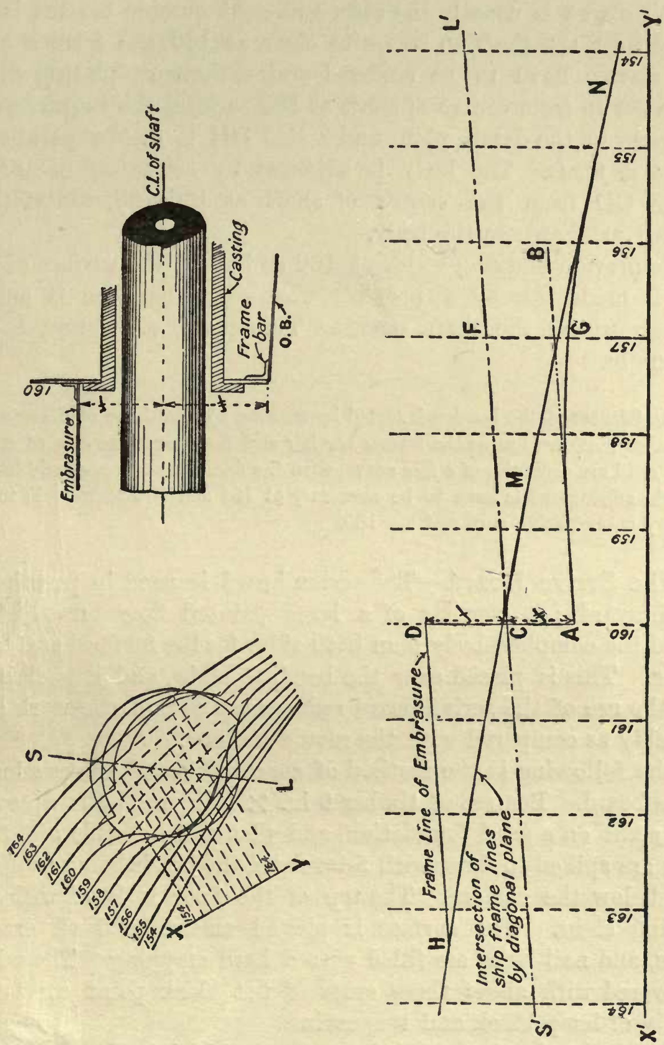


FIG. 43.

frame line must not approach the centre of shaft nearer than this. To ensure a good run of water the line AG is faired in to the intersection line MN. In the body plan sweep in circular arcs from the centre of shaft with radii as AC at 160 and FG at 157, and continue to the frame line with the same radius at the top and bottom. We thus obtain new frame lines 156–160, which are shown in full.

Where, as is usually the case, sufficient outside bossing is not allowed for the shaft to be quite clear at 160, the frames abaft this station have to be recessed and embrasure plating fitted. CD is set in from centre of shaft at 160 to meet the requirements as shown in the detail plan, and a line DH is drawn parallel to centre of shaft. The body is adjusted by sweeping in arcs of radius CD from the centre of shaft at 160–163, the stations affected, as shown in the body.

To prevent eddying water at 160 and abaft, the surface of the ship is made fair by a portable wash-plate between H and A through which the shaft passes. This plate, of course, is not watertight.

The fairness of the bossing is tested by running off the shape ot diagonals in the hollow portions, but as the frames are fair and the curves are arcs of circles whose radii are ordinates of a fair curve, then the final frame lines should be fair. A slight adjustment is seen to be necessary at 161 and 162 to wipe in to the ordinary outer bottom surface from 160.

The Scrive Board.—The scrive board is used in practically all shipyards; it consists of a large painted floor on which is copied the complete body plan both sides for the forward and after bodies. This is placed near the bending slabs, and it is claimed that the use of the scrive board reduces the cost of the work considerably as compared with the mould method.

The following is the method of construction of one particular scrive board. Bearers of timber 6 in. × 8 in. are built up every 6 ft. apart on a good foundation, and planks 6 in. wide and 3 in. thick are spiked to them with 5-in. nails, the heads being punched well below the surface. The top of the floor is level with the bending slabs. The surface is planed smooth and all cracks, seams, and nail holes are filled with a hard stopping. The whole is covered with about three coats of flat black paint consisting mainly of lamp black and turpentine.

The body plan is copied from the mould loft floor by transferring a series of spots from water-lines, levels, and diagonals on battens. The arrangement on the scrive board must be different from that on the floor, because a double body plan is required, *i.e.* both port and starboard side must be shown. Unless there is room for two complete body plans (and there rarely is) overlapping must occur. Fig. 44 shows one method of doing this which has considerable merit. The same middle line is used for both bodies, and also the same L.W.L. The after body is placed inverted to the fore body, and the places where congestion occurs (viz. at the floors on the lower frames) are well separated, and these are in places where comparatively few other lines cross the work. On the floor

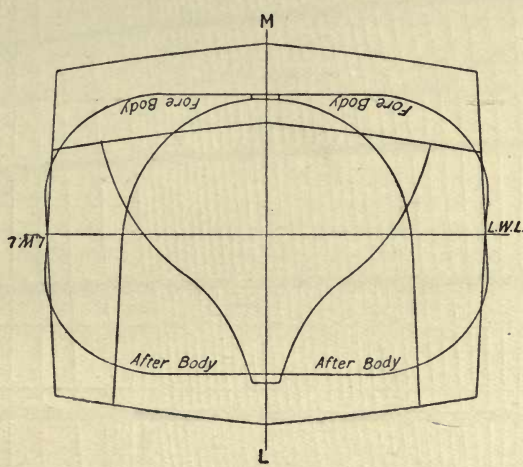


FIG. 44.

the sight edges only of outer and inner bottom plating are shown, but on the scrive board the whole of the breadth of the lap is shown as in Fig. 45. These are made conspicuous by painting, white being used for the outer bottom laps and red for the inner bottom laps.

Fig. 45 shows a half-body plan on the scrive board with all the lines required (some frames being omitted for clearness). These lines may be summarized as follows.

Frame lines of outer and inner bottoms. Decks at side and flats. Sight edges and traces of longitudinals and stringers. Plate edges of inner and outer bottoms. Traces of bilge keels and all fore and aft bulkheads. Line of beam for extreme breadth. The centres of shafts are shown for each station (being stamped on a strip of iron) and also the boss framing lines. All the lines are cut in deeply by the scrive knife described in Chap. II. If plate edges cross the frames amidships so acutely as to render the intersection indeterminate, short level lines are run at the side as in Fig. 40 (c), cut in, and the numbers stamped on a strip of iron. This

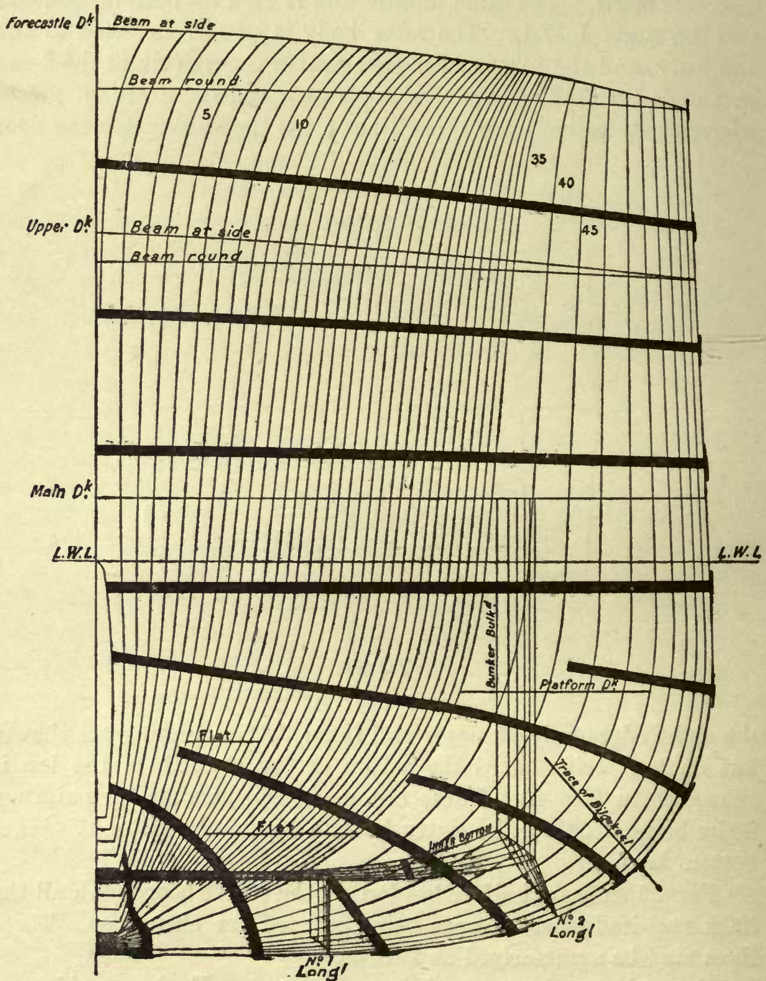


FIG. 45.

method is also adopted for any other marks which it is desirable to protect against the wear and tear which occurs on the board.

The following work can be done on the board. Bending and bevelling of frames, moulding, and assembling of floor plates, checking of boundary bars to bulkheads. Moulding of beam brackets, athwartship portions of engine and boiler bearers cut out, etc. The board forms a constant means of reference near to the smithery and bending slabs, as it is usually much nearer to the ship than the mould loft.

In regard to the use of the scrive board, which is almost universal, it is interesting to note that in H.M. Dockyard, Portsmouth, the scrive board, after being tried, is not now used. The forward and after bodies, after being faired, are *scrived in* on the mould loft floor, and all the information is sent out into the yard in the shape of moulds. It is claimed that this results in considerable economies in the special case of warships where practically all the framing is made of short pieces, and moulds for them can be readily made and easily transported. Congestion on the scrive board is avoided, and the transporting of the framing for checking purposes is not necessary. It is admitted that where frames are in long lengths a scrive board adjacent to the bending slabs is a necessity. It is claimed that the time taken in transferring the body to the scrive board from the floor is saved, and information regarding the shapes of frames can be sent out very early for the midship portion of the ship. Portsmouth Dockyard undoubtedly is able, by the methods adopted and by the extensive use of moulds, to make very rapid progress in building; of course, all the workmen concerned are familiar with the system. In merchant yards everybody is familiar with the scrive-board system, and when a warship is built in such a yard the natural method is to adopt the same system.

CHAPTER IV

MODELS

The Half-block Model.—A half-block model is always constructed for the purpose of arranging the edges and butts of the outer bottom plating on the surface of the vessel. Such models are usually made to the scale of $\frac{1}{2}$ in. to the foot, sometimes to the scale of $\frac{1}{4}$ in. to the foot; this depends on the size of the vessel. The method of construction varies in different yards, and it is proposed to describe two methods.

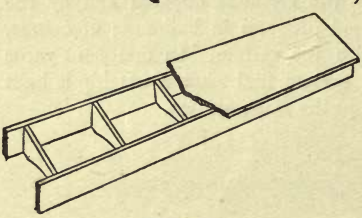


FIG. 46.

A model should be built upon a true flat backboard, the style shown in Fig. 46 being recommended. The framework is prepared as shown, the upper edges being in a true plane to take the backboard. This board is fastened from beneath by screws as indicated in Fig. 47. The framework for a model of a vessel 500 ft. long on the $\frac{1}{2}$ in. scale would be formed of $1\frac{1}{4}$ in. plank with a backboard of the same thickness. The width, of course, will depend on the depth of the ship. When the backboard is fixed it is planed up true and smoothed with sandpaper.

FIG. 47.

The profile of the vessel is now drawn on the board with the position of the L.W.L. and each ordinate, also the perpendiculars and two lines parallel to the L.W.L., one well clear above and one well clear below the profile.

The modeller is provided with a body plan of the vessel to the required scale, which is sufficiently fair for the purpose of constructing the model.

First Method of Construction.—A half-section for each ordinate is made of wood about $\frac{1}{2}$ in. short of the shape of the contour of the section, one edge of which coincides with the middle line. These sections are made thick enough to obtain a good hold for the screws through the backboard. The L.W.L. is marked on each. These sections are then screwed in the proper positions through the backboard, the L.W.L. being well in each case. The contour of the stem and stern post are constructed solid and secured in their proper positions. The whole surface is then covered with narrow battens of such a thickness that sufficient material is allowed for cleaning off (Fig. 48). These battens are let into the solid pieces at the stem and stern, to which they are glued and screwed. The sections are bevelled to suit the run of the battens, and these battens are glued and screwed into them. The heads of the screws are sunk well below the surface.

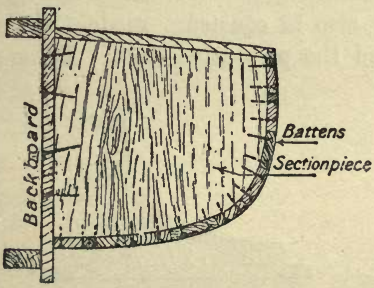


FIG. 48.

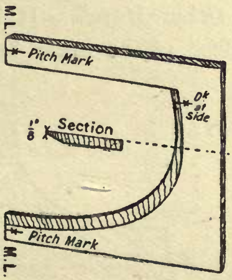


FIG. 49.

The surface has now to be faired down to the correct shape. For each of the ordinates an outside mould is made from the body plan, of thin board with a chamfered edge as in Fig. 49. The position of the lower and upper base lines and the deck at side are marked on. The surface of the model is now carefully chased until all the moulds fit in their proper relative positions as defined by the position of the base lines, and the surface is fair and true. After being thoroughly sandpapered, the model is coated with priming, and the screw heads and any small cracks are filled up with putty. The surface is then finished off with a flat white or grey paint. Fig. 48 shows a section of a model built up by this method.

Second Method of Construction.—In this method, which is more often used for small-sized models, the model is built up in layers. Parallel lines are drawn on the body plan, the L.W.L. being one.

Planks are planed of thickness exactly equal to the distance apart of the level lines, and the positions of the ordinates are placed upon them. The shape of a level line is drawn in upon each board, and the outer portion is cut off to within about ¼ in. of this curved line in each case. The middle line is shot up true and square in each case. Each of the boards is screwed into position on the backboard and glued, pegged, or screwed to the one immediately beneath it. As much as possible of the inside of the wood is cut out for the sake of lightness, and the top piece forms the deck. The surface is then faired as described above; a section of the finished model is shown in Fig. 50.

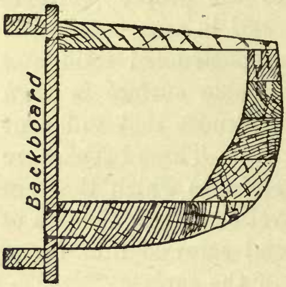


FIG. 50.

Other Models.—It is usual also to construct models for the surface of the inner bottom and the protective deck. These are

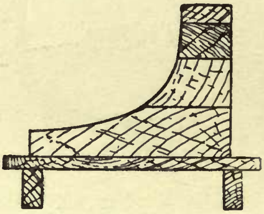


FIG. 51.

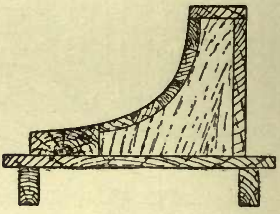


FIG. 52.

constructed on similar principles to those described above, solid or built up as may prove convenient. Fig. 51 shows the section

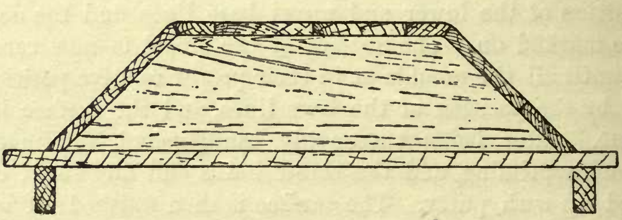


FIG. 53.

of a solid inner bottom model; Fig. 52 shows a built-up inner bottom model; and Fig. 53 a built-up model of a turtle-back protective deck as usually built in war vessels.

For war vessels it is usual to construct a complete model of the portion of the vessel above the load water-plane with all superstructures and rig. Such a model is of great assistance in arranging leads for boat-hoisting gear, torpedo net defence, coaling arrangements, etc. In order to arrange snug stowage of stockless anchors, models are sometimes made which can be experimented with until a satisfactory hawse pipe is obtained.

Lining Off the Half-block Model.—The sections which were drawn in on the backboard enable the positions of the frame stations to be determined. Each frame is marked on the backboard above and below the profile, and the run of each frame on the surface is marked on by some such method as the following.

A wood bracket sufficiently large to embrace the fullest section of the model is used, with brackets made so that it

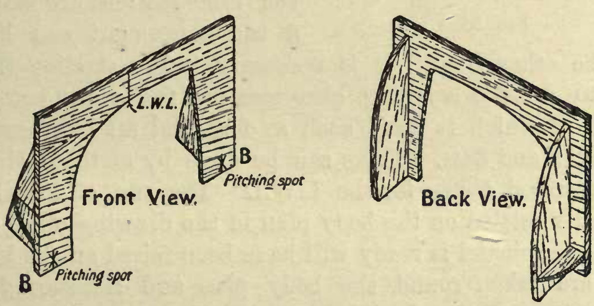


Fig. 54.

may be kept perfectly square to the backboard. Such a bracket is shown in Fig. 54. The bracket is placed so that the pen with its holder flat on the bracket coincides with the position of a frame station on the backboard. The frame line can then be put in right round the section and will be properly square to the middle line plane of the model. One method of holding the pen or pointer is shown in Fig. 55. The wooden handle containing the pen has one flat surface which is held on the surface of the wood bracket as the pen traces out the frame line round the section.

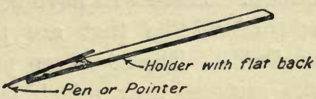


Fig. 55.

To mark in the Load Water-line.—Two marks are placed on the bracket at X and X, the distance apart of the base lines on the backboard. The position also of the L.W.L. is marked on by a straight line square to BB, and in correct relation to the marks X. The bracket is then placed with the base lines correctly pitched, and the pen or pointer applied to the surface with one edge of the holder well with the line L.W.L. A number of spots on the model are thus obtained, and the L.W.L. can then be faired in with a batten. The battens used for model work are usually of yellow pine about $\frac{1}{2}$ in. wide and $\frac{1}{16}$ in. thick, the edges being carefully faired. They are held in place on the model with pins pushed through the middle, see Fig. 56. Battens wide in proportion to the thickness are best for outer bottom work generally, as fairer lines are obtained by their use. After the L.W.L. and the frame stations are marked on, a commencement can be made with the other lines. It is necessary before starting the plate edges to draw everything else meeting the outer bottom, the position of which is fixed, such as fore and aft bulkheads, bilge keel, decks and flats. These can be done by methods similar to that described above for the L.W.L. The run of longitudinals are usually settled on the body plan in the drawing office, and by the time the model is ready will have been faired on the loft floor. Girths are taken round the body plan and transferred to the model by means of a flexible scale. It is necessary to place all these on the model, as they are more or less fixed in position by the requirements of the design, while the edges of the outer bottom plating are to a certain extent capable of being shifted to clear the other lines.

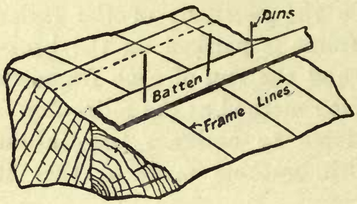


FIG. 56.

The arrangement of the plate edges round the midship section will be shown on the sectional drawing which is part of the design. These will have been arranged to clear the longitudinals and of widths that are practicable, with the yard machinery available. The edges are placed on the model by girthing round the sections near midships. The keel and the garboard strake are run along parallel to the middle line, and it is usual to run two complete strakes in the vicinity of the L.W.L. In running in plate edges it is desirable to let the batten lie flat on the model without undue restraint, as by this means we obtain plates whose edges will be practically straight when developed, and the form of the plates will be such that they fit the frames easily. It is desirable to arrange a strake of plating to take the bilge keel over its whole length in order to avoid the bilge keel crossing the edges. As the ends of the ship are reached it will be found that the girth is considerably less than that amidships, and if the same number of strakes were worked they would be unnecessarily narrow. Some strakes are therefore dropped. This may be done (1) by the method shown in Fig. 57, where two strakes are stopped at a butt and one strake takes the place of two, or (2) by using a *stealer* as shown in Fig. 58.

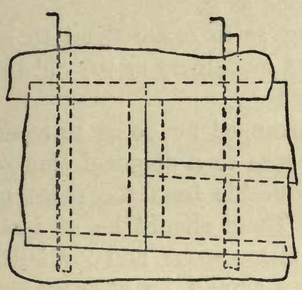


FIG. 57.

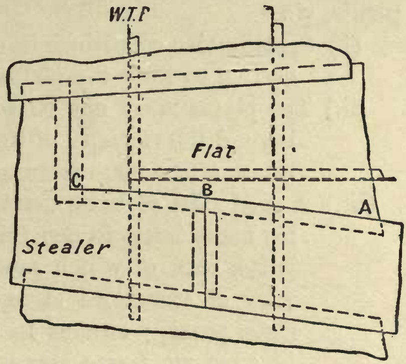


FIG. 58.

Fig. 58 illustrates a case in which a stealer *had* to be adopted rather than the other method. A flat was in the position shown, and the plate edge AB was running in such a direction that it would cross the flat. It was not possible to place a butt to both strakes at B because the single plate to take their place would

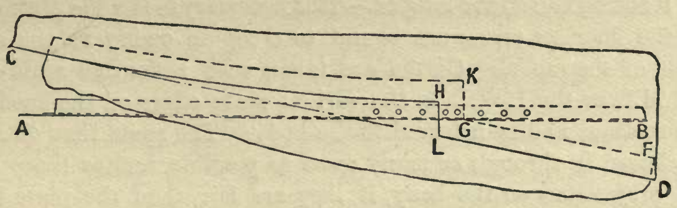


FIG. 59.

have been too wide. The edge BC was therefore kept clear of the flat and the butts placed as shown with a *stealer* or *chopper* plate.

It is sometimes impossible to avoid the general run of a plate edge crossing a longitudinal or flat. Unless the following arrangement is made satisfactory riveting is impossible. In Fig. 59, AB is the run of the longitudinal or deck with its connecting angle, and CD is the run of a plate edge. Draw in FG the width of the lap from DL. At G draw GK square to AB and LH the width of the lap away. The plate edge above the flat is then faired in to the point H as shown just clear of the angle bar. It is seen by this means that only two rivets in the angle bar are disturbed, and efficient riveting can be secured.

Arrangement of Butts.—When the plate edges are run in the butts can then be arranged. We have to keep in mind several points, viz.—

(i.) Specification conditions regarding lengths, it being generally desired to work the plates as long as possible;

(ii.) The plates must not be so long as to cause them to be beyond the capacity of the yard machinery or beyond the limits of the manufacturer; and

(iii.) A good shift of butts must be arranged for, so as to avoid too many butts in one frame space or a diagonal line of butts, both of which are undesirable from the point of view of structural strength. There should be at least three passing strakes in one frame space, and for butts in adjacent frame spaces there should be at least one passing strake. Where butts occur in consecutive strakes they should be at least two frame spaces apart. On no account must butts be stepped, as this gives a diagonal line of weakness. With the long plates now usual there is no difficulty in complying with any of these conditions. A specimen shift of butts is given in Fig. 60.

Fairing the Plate Edges.—It is necessary to fair the plate edges on the floor, as errors are bound to creep in owing to the small scale of the model. Girths are taken with a flexible scale from the M.L. or the L.W.L to the various plate edges on the model at the sections and transferred to the body. The spots thus obtained are faired in through as many spots as possible, and as these lines are projections on the body, if they are fair, then the plate edges on the ship will also be fair. It is necessary to fair independently the plate edges between the fore and after bodies where the stations are so close as to give indeterminate intersections. This fairing is done on a contracted scale. In Fig. 61 let AB and CD be the plate edges in the fore body and after body respectively. Take off on a short batten the heights of the intersections from the nearest level line. (If the plate edge is below the bilge, a bow or

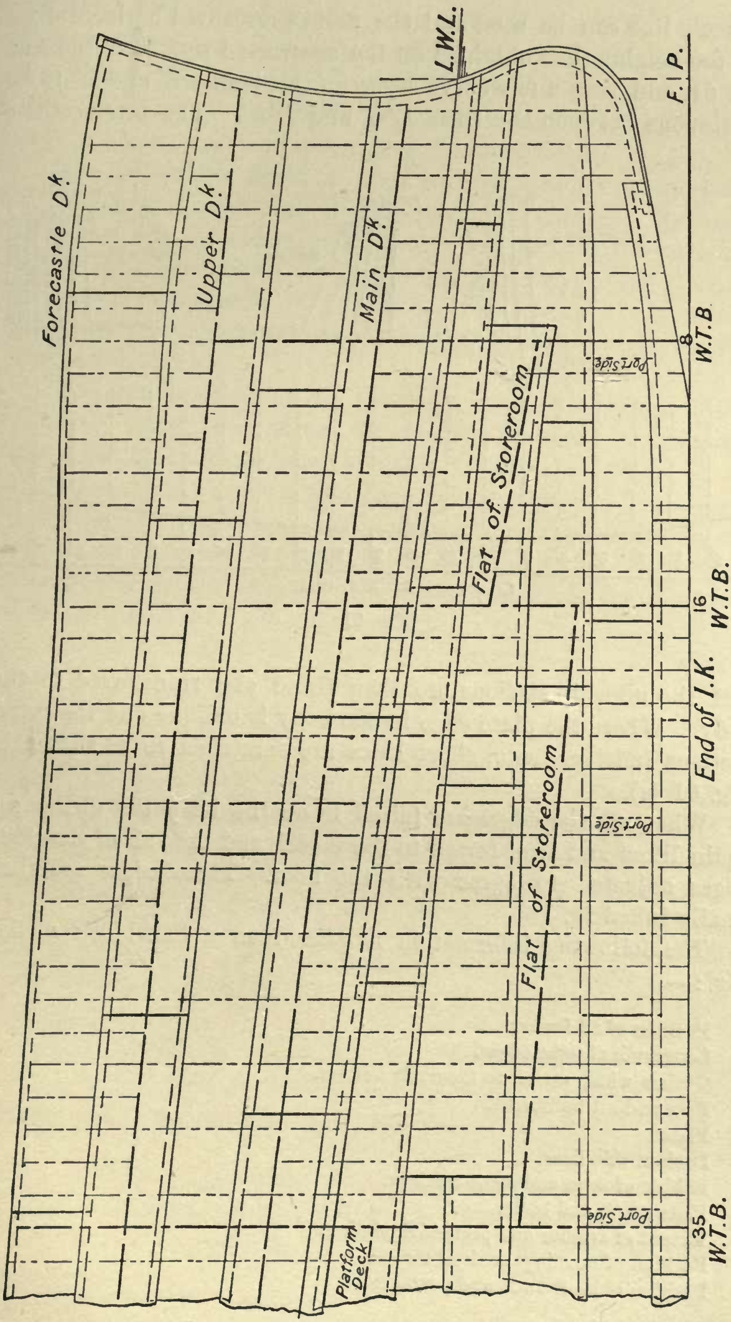

L.W.L.
F. P.
Forecastle Dk.
Upper Dk.
Main Dk.
8 W.T.B.
Port Side
Flat of Storeroom
16 W.T.B.
End of I.K.
Port Side
Flat of Storeroom
35 W.T.B.
Port Side
Platform Deck

FIG. 60.

buttock line can be used and the points measured horizontally.) Set the heights thus obtained on the contracted square stations as Fig. 61, and pass a fair curve between the points B′ and C′ to be continuous between the lines D′C′ and B′A′. The intersections

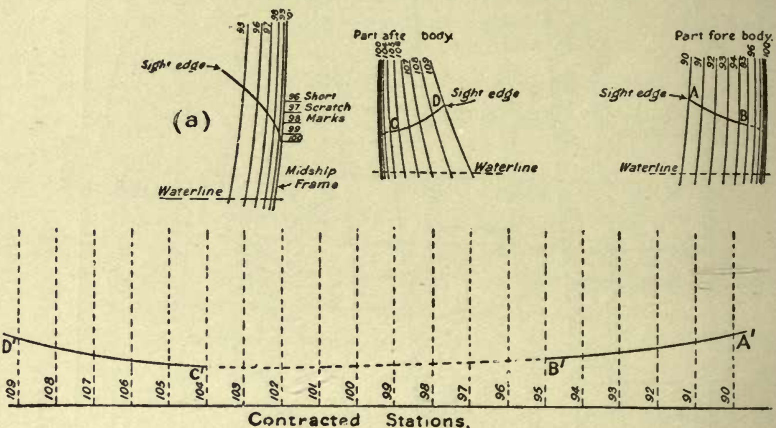


Fig. 61.

with the midship stations are then lifted and transferred to the body. Where the plate edge in the body is oblique and the intersections indeterminate, short lines are scratched in as shown in Fig. 61 (a).

When all the edges are faired in on the body the girths are again lifted and transferred to the model, and the run of the plate edges adjusted to agree with the floor. These edges are then finally inked in.

The following information is placed on a half-block model, viz.:—

Position of all frames.
Longitudinal sight edges.
Girders which attach to the outer bottom.
Fore and aft bulkheads.
Flats.
Deck at side lines.
Rabbet of stem and stern castings.
Plate edges and butts.
Extent of armour and protective plating.
Position of openings such as torpedo tubes.
Position of shaft swell and portholes.

Some distinctive difference is made for the port side of the ship if any of the above items are different from the starboard side, for which side the model is usually constructed. A convenient method is to draw frames in blue; butts, edges, etc., on starboard side in black; and port side in red where different.

The half-block model is used to construct the outer bottom expansion drawing which is sent out into the yard. The lengths of plates for demand purposes are measured from the model, but the widths are taken from the body plans on the floor, due allowance being made for the width of the laps. It is usual to mark on the model on each plate the demand number and the size and poundage.

The model will show to the yard people those plates which require "firing," and these can then be prepared in advance of the vessel being framed, and so delay may be avoided.

Other models are lined out on similar principles to the above. A deck model would have the position of beams, bulkheads, plate edges and butts and openings shown on. An inner bottom model would have similar lines to those on the half-block model together with the position of the manholes.

Expansion of Outer Bottom Plating.—Fig. 60 shows a specimen shift of butts arranged on a drawing known as the expansion of outer bottom. This drawing is practically a copy of the lines on the model, and it is made by first setting off the frame spaces to scale and drawing in lines square to a line representing the underside of keel. Measurements are taken from the model round each frame, all plate edges, flats, decks, etc., being marked and also the L.W.L. These girths are set out on the respective stations from the base line, and the spots on any one plate edge, etc., are connected by as fair a line as possible; thus the outer bottom edges are *expanded*. All the butts are copied from the model to the drawing; this forms a portable copy of the surface of the model.

The expansion shown in Fig. 60 is for the fore end of a vessel of similar class to that for which the body has been drawn to illustrate the scrive board (see Fig. 45).

CHAPTER V

MOULD WORK ON THE FLOOR

AFTER the vessel has been laid off, moulds are made for various parts of the structure, and information is given on battens for the use of the workmen erecting the structure of the ship. The practice in different yards and localities varies considerably in this respect, but the practice of sending out moulds from the mould loft is becoming very general, even to the extent, for example, of sending out moulds with every hole marked on ready for transferring to the plate.

The following is a specimen list, and the order given is about the order in which the moulds are sent out:—

Declivity of blocks.
Contour of forward and after blocks for trimming and checking.
Midship section.
Stem and stern.
Keel staff.
Flat keel sections and vertical keel.
Longitudinals.
Frames (if no scrive board).
Fore and aft bulkheads.
Bottom plates with twist and curvature.
Stringers of flats and decks.
Beam round, beam spread, and beam arms.
Stem casting, stern castings, shaft brackets, and rudder frame.
Engine girders and boiler girders.
Bilge keel plates, erection moulds and sections of timber filling.
Armour.
Davits.
Holes in deck and side for hawse pipe.
Lifting battens, etc.
Other moulds required for the particular type of vessel as necessity arises.

It may be mentioned, as a general rule, that moulds should be well braced to prevent distortion, and a straight line marked across the various battens forming the mould, which may be checked to see *that no distortion has taken place. Examples will be seen in the various figures illustrating the present chapter.*

Mould for the Declivity of Blocks.—This is made in order that the upper surface of the blocks, on which the ship is to be built, may be trimmed correctly to the proper declivity, after the top of blocks has been sighted in.

Set off on a line a distance of about 20 feet as AB, Fig. 62. At A and B square down AC and BD, making AC = 1 ft., say, and BD the necessary length, so that the angle between AB

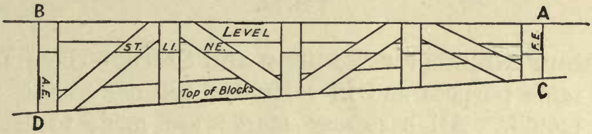


FIG. 62.

and CD is the inclination of the blocks to a level line. Thus for a declivity of $\frac{5}{8}$ in. to the foot with the above dimensions, BD = $24\frac{1}{2}$ in. The mould is made to the shape ABDC, as shown.

Moulds for trimming and checking the Blocks before and abaft the Straight Part of Keel.—These moulds are made from the points of the "cut-up" forward and aft, those for the forward end being shaped as shown in Fig. 63; the after ones are on similar lines.

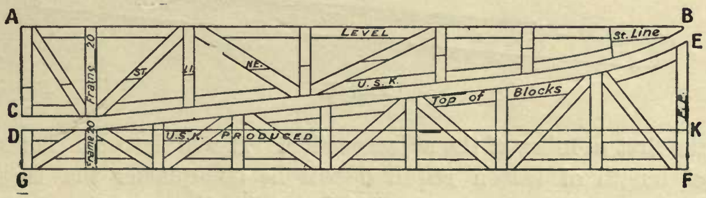


FIG. 63.

The mould DEFG is made with the edge DE to the *underside of keel* as laid off in the sheer plan, and the line DK (underside of keel produced) is scratched across the battens. The mould ABC is just a reverse, and is used as a check on the blocks when trimmed, AB being in a level line.

Midship Section Mould.—Sometimes made for observation purposes on the slipway, and would be in three or more pieces, as shown in Fig. 64, to facilitate transporting. The outline is made to the outside of plating to just above the turn of bilge. The distance of the tops CD below the L.W.L. is given.

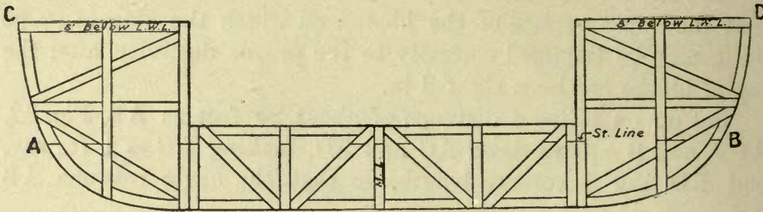


Fig. 64.

Contour Moulds for the Stem and Stern.—These are made for the same purpose and in a similar manner to the midship section mould. All necessary marks are made to locate the position of the mould, as *e.g.* the F.P. on the forward mould, and the L.W.L.

Keel Staff.—A set of battens, each about 30 ft. long and from $1\frac{1}{4}$ in. to $1\frac{3}{4}$ in. square in section, is prepared. On these the spacing of the frames are accurately set out. All four sides of the battens are used, and each frame, with its number (and description whether oil-tight (O.T.) or water-tight (W.T.)), is marked on. Also the butts of the outer keel (O.K.), inner keel (I.K.), and vertical keel (V.K.) are marked on. The last frame number on one side

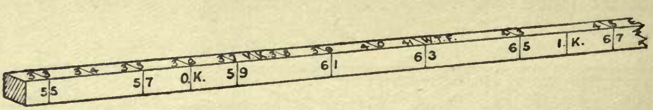


Fig. 65.

is the first number of the adjacent side. It will be seen that the total length of batten required will be one-quarter the length of the vessel between perpendiculars. Fig. 65 shows the method of marking.

Flat Keel Sections.—Section moulds are supplied for each end of each outer keel plate, and also a section at the middle. These are not required where the bottom of the ship is flat. The top edges of the moulds "outwind," and the plate edges and middle line are marked on each. The thickness of the inner keel must be allowed for outside the frame line. In way of the cut-up, flight moulds are also supplied. For the inner keel a mould is only made at each end, and others needed should be made from the outer keel plates so that a true fit may be obtained. The moulds made on the floor can be taken directly from the body plan, as Fig. 66.

A convenient method of making these moulds, which assures exact similarity between the two sides, is as follows : A piece of tracing paper is folded and the crease applied to the middle line. The outline of the section is traced on and the plate edge and the top of mould. The paper is then folded and the above pricked through, and in this way the complete section is obtained. The top of mould is then perfectly square to the middle line.

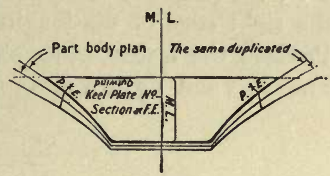


FIG. 66.

Vertical Keel Moulds.—It is frequently the case that the vertical keel varies in depth ; thus, in a certain ship it was 36 in. deep in engine-room, 33 in. deep for 140 ft. forward and 40 ft. abaft the engine-room, and 21 in. deep at the ends, where the longitudinal strength is not so necessary. To avoid discontinuity of strength the break from one depth to another is made over a length of about 4 ft., and it is for the plates where the change in depth occurs that moulds are necessary. It is not usual to provide moulds for parallel plates, the information contained on the working sketches being generally sufficient.

In lining off vertical keel plates, allowance should be made for the varying thickness of the flat keel plating. In Fig. 67 let XY represent the base line and 1, 2 . . . 7 the frames. Set off below

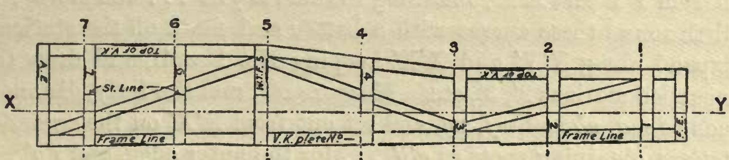


FIG. 67.

XY on the respective stations the depth of the frame line taken from the frame lifting batten (see p. 91). This will show the necessary joggles at the lower edge. The shape of the upper edge would be fixed as described later.

It should be noted that the battens on the mould having one edge at the frame line should be placed to cover the flange of the frame connecting bar, so that the rivets can be marked upon the batten for transference to the plate.

The Longitudinal.—Any twisted surface which has straight lines for its traces on a series of parallel planes can be developed, *i.e.* laid out flat. The longitudinal is such a surface, and the methods here detailed can be applied to any similar case.

Longitudinal with little Twist and Curvature.—Let 1 . . . 5 (Fig. 68) be square stations in the body, *ab* . . . *e* being the sight edge of the longitudinal and *fg* . . . *l* the inner edge. Produce the traces *af*, *bg*, etc., both ways, and draw two parallel lines X*m* and Y*q* at a mean normal to the traces.

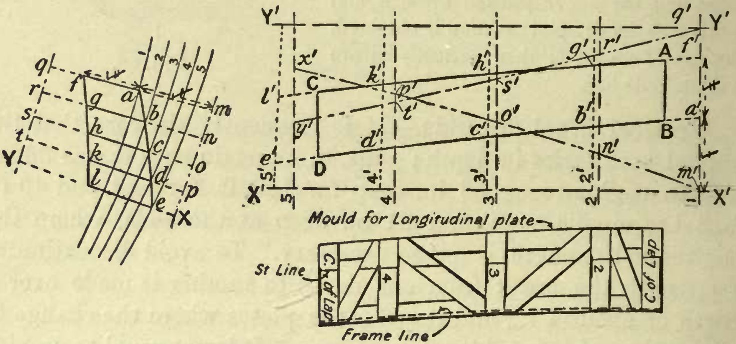


Fig. 68.

In the half-breadth, set out the stations 1 . . . 5 and two parallel lines X′X′ and Y′Y′ the distance XY apart. Lift the distances of *r*, *s*, etc., from *q* and *n*, *o*, etc., from *m*, and set these off from Y′Y′ and X′X′, obtaining the curves *q′r′s′* . . . and *m′n′o′* . . . Girth round these curves with a batten and mark off the stations. Expand along Y′Y′ and X′X′ keeping No. 1 well, and draw the expanded stations 2′, 3′, etc. Measure off from the body, distances such as *ma*, *nb* and *mf*, *ng*, and set out from X′X′ on the *expanded stations,* obtaining spots as *a′b′* . . . for the outer edge, and *f′g′* . . . for the inner edge. The curve *a′b′* . . . *e′* is then the expanded outer edge, and *f′g′* . . . *l′* the expanded inner edge. Mark off the butts as AB and CD and make moulds with a batten to each butt and at each station *on the side where rivet holes for the angle connection to frame have to be punched.* The mould has to be full of the frame line to allow for the thickness of the inside strake.

Longitudinal with much Twist and Curvature.—Apply the same construction as above, except that the lines X*p* . . . *m* and Y*t* . . . *q*, Fig. 69, are made up of mean normals to the consecutive traces. *Great care is necessary in setting out these two lines, as*

on this the accuracy of the development entirely depends. One of the methods outlined below will ensure correct results.

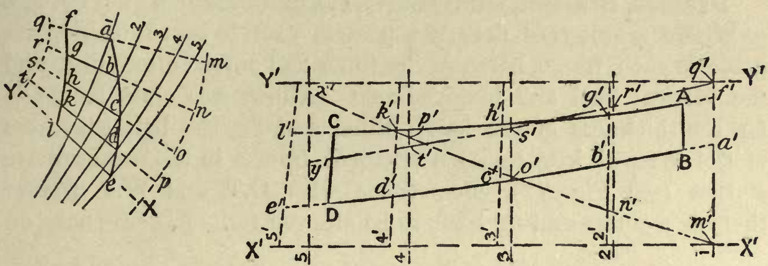


FIG. 69.

Longitudinal with much Twist (Fig. 70).—Produce the traces to meet. With centre *a*, where trace 1 meets trace 2, and with radius *aq*, draw an arc to *r*. Then with centre *b*, where traces 2 and 3 meet, draw an arc with radius *br* to meet trace 3 in *s*, and so on to Y. The curve *mn* . . . X is obtained similarly. The lengths YX, *tp*, etc., are obviously all equal, and the lines X*p* . . . *m* and Y*t* . . . *q* will expand into two parallel straight lines. A longitudinal which twists into a flat is an example of the above.

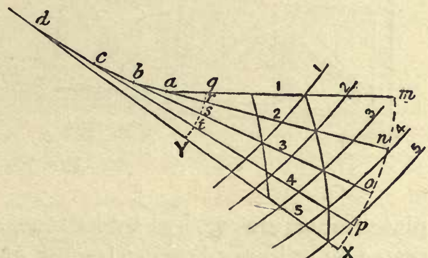


FIG. 70.

Longitudinal with much Curvature but little Twist.—In this case the traces would have to be produced inconveniently far to adopt the previous method. In Fig. 71 let 1, 2 . . . 7 be the traces. Take any point *a* in 7 and draw *ab* square to 7 to meet 6 in *b*, and draw *bc* square to 6 to meet 5 in *c*, and so on to *g*. From a point *h*, about 1 in. from *g*, go backwards in a similar manner to *p*. Then bisect all such distances as *ap*, *bo*, etc., and draw in a curve XW . . . R, which is a mean normal to all the traces. Get the curve YZ by cutting off equal distances from XR. A longitudinal diverted to fair into a fore and aft bulkhead is one example of this case.

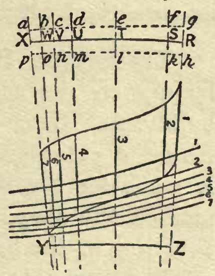


FIG. 71.

By careful application of one or other of the above methods any longitudinal can be developed without the necessity for mocking up.

Frames, Bracket, Oil-tight (O.T.), and Water-tight (W.T.).—Where a shipyard does not possess a scrive board, moulds are made to each frame, between the inner and outer bottom lines and the vertical keel and longitudinals. Allowances must be made for the thickness of the longitudinal and for the half thickness of the vertical keel between adjacent frames in the same square station (see Fig. 72). Sometimes with O.T. and W.T. frames there is a compensating liner to be allowed for. All stiffeners on

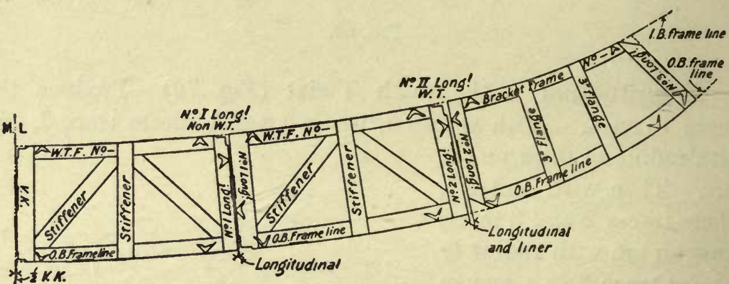


FIG. 72.

plate frames are marked by battens, and the edges of the flanged plates on ordinary bracket frames, and the bevels of the boundary bars, are marked on as shown in Fig. 72. Some yards adopt the procedure of spacing all the holes on the floor; more frequently, however, this is left for the yard workmen.

It may be stated that even where a scrive board is provided, moulds for W.T. and O.T. frames may be sent out from the floor, to avoid congestion on the scrive board. Rapid building is thus facilitated.

Transverse Bulkheads.—The form of a vessel depends largely on the accurate placing and shaping of the transverse bulkheads. Some shipyards, therefore, mould these from the body plan. A *gate mould* (which is a batten mould similar to Fig. 64) is made for the widest bulkhead (one side only), and on it is marked the shape of each of the other bulkheads, and also the bevelling of the boundary angle bars.

These moulds are used for preparing the bulkhead plating, which is laid out on boards.

Fore and Aft Bulkheads.—At the forward and after ends of a vessel some bulkheads run down to meet the outer bottom.

The bottom plates of such bulkheads have sometimes considerable curvature along the lower edge, and the boundary bars have a good deal of bevel. These plates are moulded as follows:—

In Fig. 73 let AB be the trace of the bulkhead in the body plan, cutting the frames numbered 1 . . . 5 at *a* . . . *e*. Project

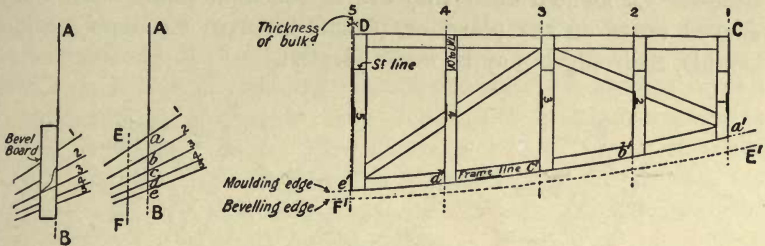


Fig. 73.

a . . . *e* to the sheer and pass a fair curve *a'b'*. . . . *e'* through the spots. Draw in CD to represent the top of the plate.

If the bulkhead came on a raised strake of plating, the line *a'* . . . *e'* would have to be lowered an amount equal to the mean thickness of the adjacent sunken strakes. This could be done by lifting DC a corresponding amount.

The mould is formed as shown between the lines DC and *a'* . . . *e'* and the ends of the bulkhead, say at 1 and 5, making the necessary allowance for the thickness of the bulkhead at 5.

The straight line struck on the mould should be a convenient stated distance from the L.W.L., deck line, or other handy datum line.

If the curvature of the line *a'* . . . *e'* is not excessive, the bevels of the boundary bar may be obtained directly from the body plan, as shown at station 3. In extreme cases draw a line EF, about 4 in. away from the bulkhead line in the body plan, and project the intersections of this line with the frames to the sheer, obtaining the line E'F'. The bevels can be measured between the lines *a'* . . . *e'* and E'F' with the aid of a bevelling board in the usual way. If the vertical bulkhead is inclined to the sheer, it can be laid off on expanded stations.

To mould an outer Bottom Plate which has considerable Twist and Curvature.—For a plate of this description moulds are made for the guidance of the platers; such plates require *firing* to bring them to the required shape. A mould termed a "flight mould" is supplied, which can be applied along a plane as nearly as possible along the middle of the length, and nearly normal to the curvature. Sections are also given which give the curvature of the plate along sections in parallel planes about square to the flight mould. These section moulds usually have their edges in the same plane in order that they may be "outwinded," *i.e.* sighted until they are in the same plane, with their curved edges on the plate, or, if this involves too deep section moulds, their edges may be made parallel.

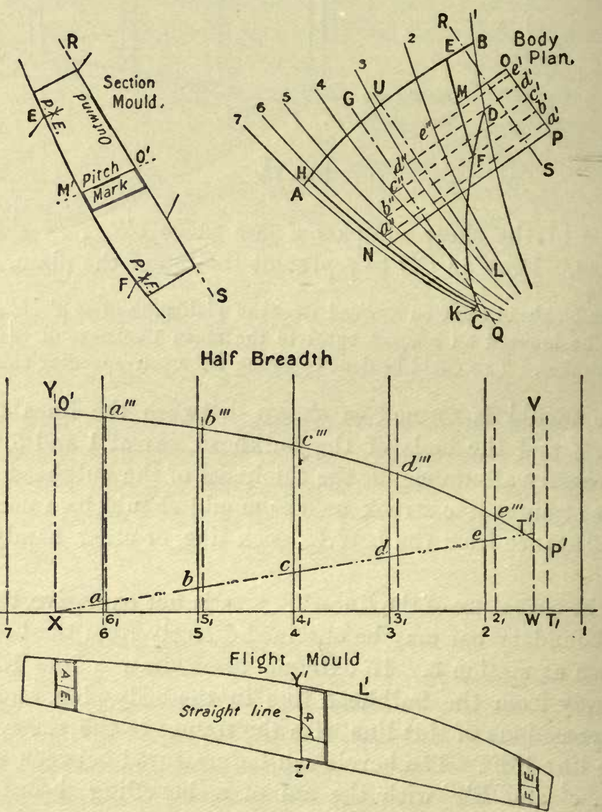


FIG. 74.

Let 1, 2, 3, etc., Fig. 74, be the frame lines in the body plan, AB and CD the upper and lower plate edges, EF, HK the end sections of the plate. Choose a point in each of the end sections as M and N, so that a straight line joining MN will be at about the middle of the plate. Draw MO, NP parallel and at about the mean normal to the sections. Draw OP perpendicular to these lines.

In the half-breadth 1, 2, 3, etc., are the square stations, XY and VW corresponding to the ends of the plate. From the base line set up on WV a length WT′ equal to OP in the body, and join XT′. Then XT′ will be the true length of the line between O and P. To find the intersections of the section planes with the plane through MO and NP, we lay a batten along XT′ and mark off X, *a*, *b*, . . . T′, and transfer to the base line keeping X well, obtaining $6_{/}$ $5_{/}$ $4_{/}$ etc., to $T_{/}$. The dotted lines are squared up through these points. The distances of XT′ from the base are then taken off at the various stations, as 6*a*, 5*b*, etc., and placed along PO, obtaining the spots *a*′, *b*′, etc. Draw lines *a*′*a*″, *b*′*b*″, etc., parallel to NP, meeting the stations in *a*″, *b*″, etc. These lines are the intersections of the station planes with the plane of the flight mould. To get the true shape of the flight mould, we set off on the expanded sections 6′*a*‴ equal to *a*′*a*″, etc., XO′ equal to PN, and $T_{/}$P′ equal to MO, and draw a curve through the spots O′, *a*‴ . . . P′. A mould made to this line, as shown in the lower part of Fig. 74, will be the flight mould which will apply to the inside of the plate. The base of the mould is made straight, and where sections are required, usually one at each end and one near the middle, the depths are transferred to the body as Y′Z′ at 4, from *c*″ along *c*″*c*′. Lines, shown in dotted, RS, UL, and GQ, are drawn perpendicular to MO. The inner edge of the section moulds are made to these lines, and being in the same plane they can be outwinded when in position. A section mould is shown in the figure. On each is marked the upper and lower edge of plate and the line of the flight mould as M′O′. As HE and CD are sight edges, an allowance must be made for the widths of laps on sunken strakes.

When the smith makes his cradle, he first bends a bar to the flight mould (allowing a thickness of plate). He then erects each section mould on this bar at the proper angle as L′Y′Z′ with the mark M′ on the centre of the bar and with the upper edges outwinding and the moulds parallel. The moulds, strictly speaking, should be placed in relation to the plane of the flight mould bar at the angle YXT′, but there is no appreciable error in pitching them square to the plane of the flight mould. The finished plate is checked by applying the moulds inside in a similar manner.

Stringer Moulds to Flats and Decks.—Stringer plates form a valuable means of tying the ship together to the correct form, and the moulds made at the loft should be very carefully laid off.

Flats are usually level and the curve of the outer edge is readily obtained. Allowance must be made if the flat connects on to an outside strake of bottom plating.

Decks have a round down and also a sheer, and the stringer has to be expanded.

In Fig. 75 let PQ be the beam at side line in the body, PR the beam round curve, and PS any level line close under PR. 1, 2 . . . 7 are frame lines meeting the line PQ in points *a* . . . *g*. Let XY be any vertical line. Square *a* . . . *g* down, cutting PR in

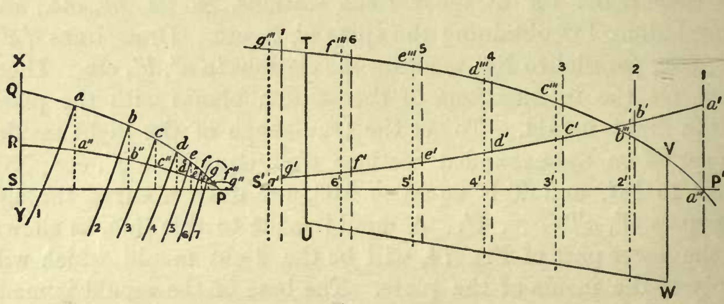


Fig. 75.

points a'', b'' . . . g''. Measure the heights of *a* . . . *g* above SP, and set them above the base line P′S′ on the respective square stations in the sheer. A curve passed through these spots a', b' . . . g' is the sheer of the deck at side. Pen a batten along a', b' . . . g' and mark each spot. Keeping a' well with No. 1, mark off the expanded lengths on P′S′ and draw the new expanded stations 2′, 3′ . . . 7′.

Pen a batten round RP marking a'', b'' . . . g'', and using any pitch-mark set off these spots on the expanded square stations at a''', b''' . . . g''', and pass a fair curve through as shown. This is the curve of the outer edge of the expanded stringer. Draw in the positions of the butts VW and TU and set off the inner edge of the stringer plate, WU, which will usually be a straight line.

In some yards a mould to the shape of WVTU would be made as in Fig. 76, but in others simply a batten would be sent out giving the breadths on each station to the outer and inner edges from the pitch line P′S′ and the distances apart of the expanded stations (if necessary).

Demands for such plates are usually prepared from sketches at an early stage, and it is desirable to check the mould with the shape as demanded to ensure that the plate can be cut to the shape. The method of doing this is indicated in Fig. 76.

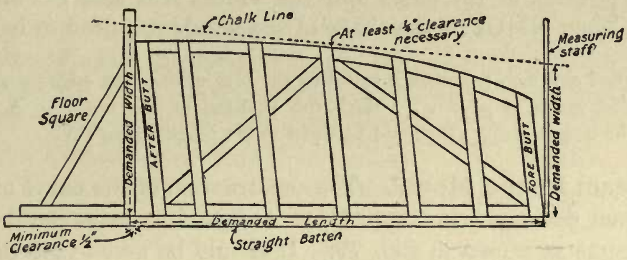


FIG. 76.

Turtle Deck.—In warships the deck just below the L.W.L. is usually sloped to a considerable angle, as shown in Fig. 77. This is done in order that shots, which may have pierced the side armour, will come up against the deck before entering the vitals of the ship, as engines, boilers, etc., and the deck by its shape would

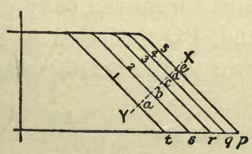


FIG. 77.

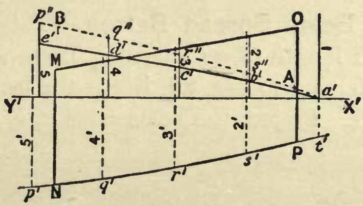


FIG. 78.

cause the shot to glance upwards or *ricochet*. Such a deck is termed a *protective deck*.

The stringer of such a deck comes on the slope and is expanded thus.

In Fig. 77, 1 . . . 5 are the stations in way of the particular plate. Draw any line XY square to the slope. Lay a batten along XY and mark off the intersections *a* . . . *e*. Using any pitch-mark set off the spots above a line X′Y′ in the half-breadth at *a′*, *b′* . . . *e′*, Fig. 78. Bend a batten through these spots and mark each intersection with the square stations. Keeping *a′* well with 1, mark off the expanded positions of the stations and draw the same, viz. 2′ . . . 5′. There will be no expansion in the width, as the deck in the body is straight for the width of the stringer. Take off on a batten the widths *at*, *bs*, etc., and set off below X′Y′ on the expanded square stations at *t*′, *s*′, etc.; this will give the shape of the curved edge of the plate. Set off at N and P the position of the butts and the widths NM and PO and join MO. Then NMOP is the shape of the mould required to be made.

A good check on the work is to set off the plan of the deck edge *pq* . . . *t* in the half-breadth at *p*″*q*″ . . . Mark the position of the butts at A and B. Then the length along AB should be equal to the length along PN.

Beam Round Mould.—The construction of the curve of beam has been described in Chap. III. A mould is made for bending the beams as shown in Fig. 79. It should be noted that the edge batten should be *shaped*, not sprung, as otherwise the mould on account of its shallowness will tend to assume the dotted shape.

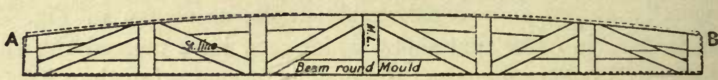


FIG. 79.

Beam Spread Batten.—This batten has marked on it the half length of each beam. These are obtained from the body plan. Referring to Fig. 80, RQ is the beam round, PQ the beam at side line. Project the beam ends *a*, *b*, etc., down to the beam curve at

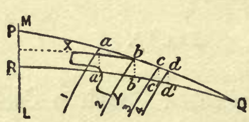


FIG. 80.

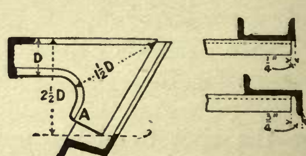


FIG. 81.

a′, *b*′, etc. Pen the batten round RQ and mark the middle line (ML) and the spots *a*′, *b*′, etc. Every beam requires some allowance for clearance from the ship's side, this varying according to the nature of the framing. If the frame is a channel or an angle bar, about $\frac{1}{4}$ in. is sufficient; but if the frame is a zed bar, at least $\frac{3}{4}$ in. is necessary in order to allow for the thickness of the flange and the round of the zed bar at the root (see Fig. 81).

Beam Arm Board.—In cabin spaces the beam arm is finished off with a rounded knee, and as each beam will have a different bevel a board is prepared having a sketch of each beam arm full size. In Fig. 80 take station 2 for example. Through b draw bX about 2 ft. long parallel to the beam curve $b'a'$ (there will be no appreciable curvature in this length). On the beam arm board, Fig. 82, AB is a straight line, CD a parallel line $2\frac{1}{2}$ or 3 times the depth of the beam (according to the instructions given). The angle XbY (Fig. 80) is transferred to the beam arm board at X$'b''$Y$'$. If there is any curvature in bY this is transferred by means of tracing paper. The shape of the arm is then filled in, having careful regard to the depth at the throat (see Fig. 81) and also that the bulb at the bottom will clear the flange of the frame bar at the point A.

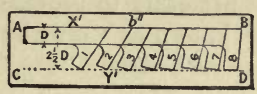


Fig. 82.

Where brackets are fitted at the ends of beams the bevels as XbY are lifted either from the scrive board or the body on the floor. The shape of brackets can be lined off on the plates from the information given on the constructional drawings.

Mould for Stem Casting.—A flat mould is made as Fig. 33 (d), showing the contour of the fore edge of stem and the back edge, and having marked on the thickness line and centre of rabbet, and also the various webs. The shape of the various sections are painted on at the places where they occur, or the shapes are supplied on pieces of tracing cloth. A straight line is marked on the mould for checking purposes. At the dockyards the pattern is made in the yard, but the usual practice is to supply the steel founder with the mould, etc., and the pattern is made by the pattern maker at the foundry works. Allowance has to be made in making the pattern for the contraction of the molten metal of the casting when cooling, and the pattern maker should be allowed some discretion in order to obtain a good flow of the metal to ensure a satisfactory casting.

Moulds for the stern-post castings are made in a similar manner. When laying off the stern-post and rudder, care has to be taken to ensure that the rudder can be unshipped when the ship is placed in dry dock.

Above the stem and stern-post castings the contour is usually formed of steel plating dished to the desired form. Wood sections are lifted from the floor for the information of the smith, obtained as described above for the stem sections.

Shaft Brackets.—The propeller shafting in vessels of the Royal Navy is supported outside the ship by means of shaft brackets. In large vessels there is a shaft bracket in front of each propeller; the next point of support of the shaft is the place at which it enters the ship, where a steel cylindrical casting is incorporated into the structure of the ship. For small vessels of fine form, in which the propellers run at high rates of revolution, it is necessary to provide another point of support, because of what is known as "centrifugal whirling." The weight of the shafting causes a certain "sag," and at high revolutions centrifugal force comes into operation which might cause serious bending of the shaft and stresses too high for safety. It would, of course, be a matter for calculation in any given case, whether it would be more economical to increase the size of the shaft or fit an additional shaft bracket.

In large vessels the shaft brackets are made of "A" quality *cast steel*. In smaller vessels and destroyers, forgings are employed as being of more trustworthy material. The rate of revolution of propellers has been the determining factor in this difference of practice.

In merchant vessels with more than one propeller it is the usual practice to boss out the hull at each shaft right up to the propeller, and a casting called a "spectacle casting" is employed which embraces the starboard and port shafts and is securely attached to the structure of the ship.

It is usually the case that the centre line of shaft is inclined both to the horizontal and vertical, this being a point of "design" determined by the arrangement of machinery, diameter of propeller, and shape of stern. In what follows it will be assumed that the centre line of shaft is inclined both to the horizontal and vertical.

The desired dimensions of the shaft bracket are given to the loftsman on a drawing; the important features being length of barrel, diameter both inside and out, section of arms and size and thickness of the palms which are attached to the structure of the ship. The length of the barrel is determined by the engineers, who fix the amount of bearing surface they require. The diameter inside will depend on the diameter of shaft and the thickness of lignum-vitæ and metal bearings. The thickness of the barrel will be fixed by the designer, as also the section of the arms.[1]

In the case of a cast steel bracket the moulds sent out from the loft are for the use of the pattern maker, who makes the pattern from which the bracket is cast. One has to bear in mind

[1] See "Theoretical Naval Architecture," by E. L. Attwood, for the strength of shaft brackets.

the fact that the pattern maker makes his pattern larger than the finished casting to allow for the shrinkage of the molten metal. Thus for the barrel, section moulds are given well clear of the ends. The smith, however, in making a forging requires moulds which he can apply to the finished job, and the forging as it leaves him must have enough metal to enable the necessary machining to be done. The pattern maker for this purpose has only to add a layer of wood to his pattern where required.

To line off a Set of Moulds for Cast Steel Shaft Brackets.—The centre line of shaft is projected into the body plan, and its intersection with each frame in the neighbourhood of the bracket is stamped on a strip of zinc or copper screwed to the floor. A convenient horizontal datum line is placed on the body plan and in the sheer, and the centre of shaft is projected in the sheer at AB, Fig. 83. The fore and aft plate on to which the upper palm is riveted may or may not be vertical, as assumed in Fig. 83. In any case the line of the surface faying with the palm is put on the body, and the intersection of this surface with each frame is squared on to the sheer, giving the line C′D′. EFGH is the barrel, and the centre line of the arms is lined in, viz. JK. Lines about 3 in. from the ends of the barrel are drawn in, viz. LM and NO, and these represent vertical planes square to the middle line plane of the ship, on which sections are made for the barrel. Where the palm enters the ship it has been the usual practice to work an angle bar right round for the purpose of securing watertightness, and in that case the shape of the palm must be continued through this angle bar before reducing to the shape of the arm, or if the change occurs within the ship the section of the arm must remain constant. Suppose PQ represents the toe of this bar. Then the arm can be rounded in as shown. The elevation of the palm and the arm are then completed. The curves joining the various portions must be well rounded to avoid discontinuity of strength, and care must be taken that the change of form from the flat palm plate to the pear-shaped arm is not commenced until the toe of the angle bar is left behind. The section at XY shows how the fore and after ends of the palm plate must be arranged to suit the framing. The top of the palm RS will usually be a horizontal straight line. Produce RS to meet LM and NO in R′ and S′.

To line off the Sections.—Project the points T and U where the centre line of shaft in the sheer meets the lines LM and NO on to the centre line of shaft in the body, giving the points T′ and U′, and scrive in two circles equal in diameter to the barrel. These will represent for all practical purposes the barrels produced to meet the planes at LM and NO. (The intersections of the barrel

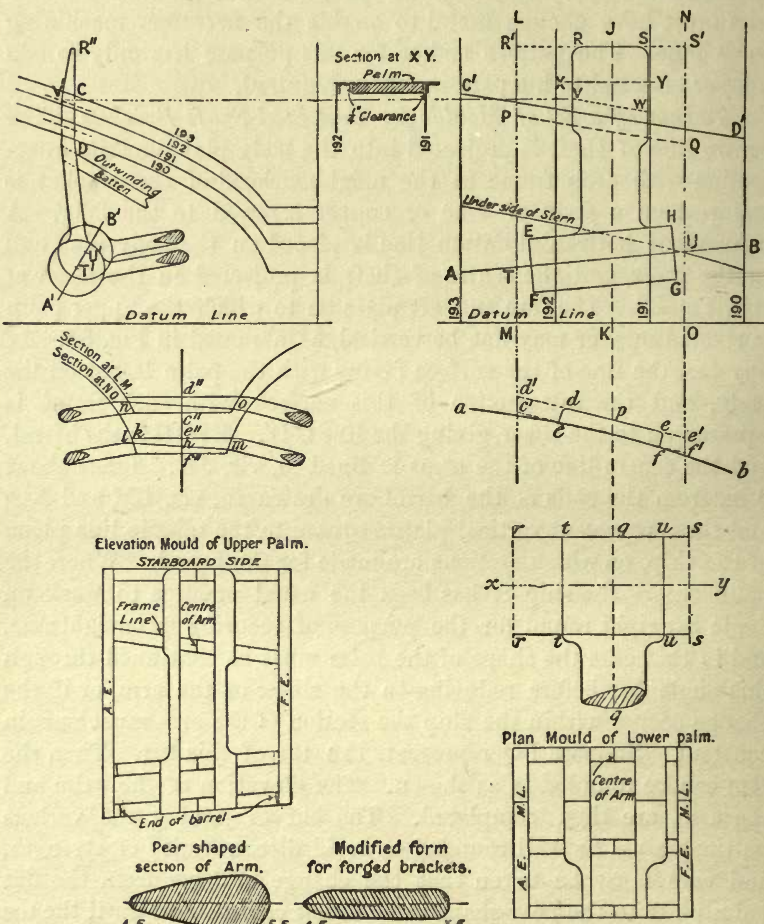


FIG. 83.

cylinder with the square-sections will not really be circles on account of the inclination of the shaft, but the error involved will be inappreciable.) Project R′ on to the body at R″ and also V, the highest point on the first row of rivets VW. The thickness here is usually specified to be a certain minimum, and similarly at R″.

The dotted lines above 192 and below 191 are the frame lines at the sections at the ends of the palm; the section of the palm must be made parallel here because of the angle bar above mentioned.

The lower arm of the bracket, in the case of a shaft bracket to an outer shaft (in a ship with four propellers), would be laid off similarly with a palm plate. For the inner shafts the lower arms of the brackets on each side will usually be scarfed together underneath a portion of the stern-post, and in this case the arm of the bracket will conform to the run of the stern-post in the neighbourhood.

In what follows the drawings have been somewhat exaggerated for the sake of clearness. The line *ab* is the contour of the stern-post and *cdef* is the recess, *de* being parallel to the line joining *c* and *f*. Produce *de* and *cf* to meet the end sections in d', e', and c', f'. Project these points on to the middle line of the body at d'', c'', e'', and f'', and draw in the shape of the end sections. The lines of the plane of the scarf *no* and *lm* are drawn parallel through the middle points of $c''d''$ and $e''f''$. These must be arranged so that the thin edge of the scarf as *kl* must not be below the specified minimum. The sections are completed by drawing the arms to the barrel sections. The plan of the palm is made to the top of the recess, and must be to the exact length of *de* and not projected. Lay a batten along $d'e'$ and mark the points d', *d*, *p*, *e*, and e'. Keeping the spot *p* well with the line *qq*, the centre of the arm, expand along the middle line of the half-breadth *xy*, marking the extent of the palm *tt* and *uu*. The shape of the palm is therefore *tuut*, where *rs* is the expanded plan of the inside of the recess. The junction of the palm with the arm is finished off as shown, the curves being gradual to avoid discontinuity of strength.

Moulds are made as shown, viz.:—

1. For the upper palm and arm.
2. For the lower palm and arm.
3. Section mould at forward plane NO.
4. Section mould at after plane LM.

On each of the two latter moulds a batten is fixed so that they can be erected in their proper relative positions with these battens "out of winding." Sections are also given showing the shape of sections through the bracket arms at convenient positions. These sections are usually pear-shaped for steel castings, with the blunt end forward.

To line off Moulds for Forged Brackets.—The centre of shaft, elevation of barrel, arm, palm, and frame-line are put down as already described. The sections for the upper arm are determined by drawing the lines LM and NO (Fig. 84) well with the ends of the barrel (with allowance for machining), and square to the centre line of shaft. The points T and U, the centres at the ends of the barrel, are projected down to T′ and U′. (Neither TU nor T′U′ is the exact length of the barrel with allowance, because they are both projections, but the difference is inappreciable and can be ignored.) Lines L′M′ and N′O′ are drawn through T′ and U′ perpendicular to centre of shaft in plan. All lines, such as the top of palm, frame-lines, etc., are produced to meet the section lines LM, NO, L′M′, and N′O′. The sections are lined off by projections into the body plan as before (the difference between the true length of LM and the projection M*m* is negligible). The sections of the stern casting used for the laying off of the lower palms are those at Z and Y. Each section which has to be machined has a strip of the necessary thickness either tacked on or cut on the moulds for the sections. The mould for the elevation is made between LM and NO, and that for the plan is developed on the middle-line lengths as before, the expanded sections being kept parallel to the lines L′M′ and N′O′. The section moulds thus supplied apply directly to the ends of the finished forging of the barrel, and the elevation and plan moulds check the angle of the arms with the centre line of the shaft.

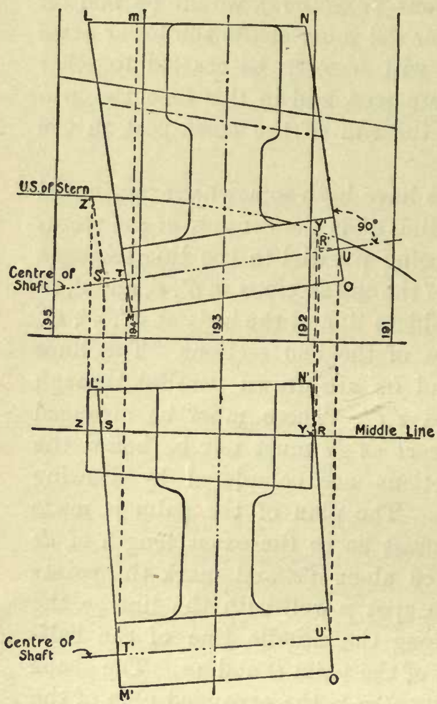


Fig. 84.

It is as well to check the moulds by marking the centre of the arm on each of the elevation and plan moulds and across the barrel. Then, by screwing them in position between the sections, these marks should be in one plane.

The section of the arm of a forged bracket is usually formed as shown in Fig. 83.

Where shaft brackets are of simple design, it is sometimes sufficient to supply a full-size drawing of a section through the centre of the arm on loose boards, the shapes of the palms being obtained by the pattern maker from the sketch. If there is any "run" on the shaft, the position of the centres at the ends of the barrel would be marked as at *a* and *b*, Fig. 85.

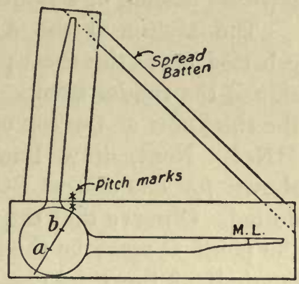


FIG. 85.

Some contractors for forged shaft brackets prefer to work from skeleton patterns. The moulds necessary to prepare these are the same as are required for cast brackets; the pattern maker in this case makes no allowance for shrinkage.

Rudder Frame.—Rudder frames are usually of cast steel; for merchant vessels they are sometimes made of forgings.

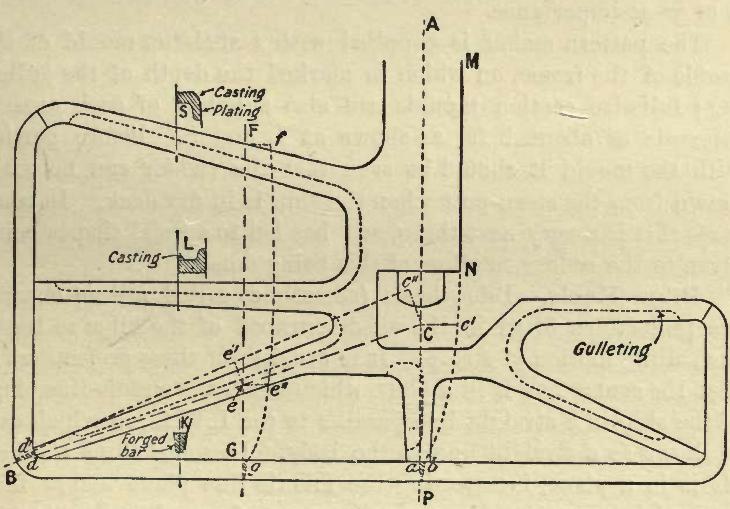


FIG. 86.

For a forged rudder frame the smith would be supplied with a full-size sketch on a board with the necessary sections.

For a cast-steel rudder frame as fitted in war vessels it is necessary to fair the lines on the floor. The outline is first copied full size from the detail drawing (as Fig. 86), and various sections are laid off. The outer edges are often formed of a separate casting or a forging, as shown at K, Fig. 86.

The section at the AP, *i.e.* at the centre of rudder-head, is rabatted on to the sheer; the portion MN will coincide with the side of the rudder stock. At the point *a* set out *ab* equal to half the thickness of the top of the edge bar, and line in a fair curve, MN$c'b$. Next, draw lines through the centre of each arm, as shown for one case at BC, and rabat the section down as shown dotted. Observe that the breadth of the sections at AP and BC at the point C must be the same, *i.e.* $Cc' = Cc''$, and that dd' equals one-half of the thickness of the edge bar. Each arm is treated similarly, and then a series of vertical sections, about 2 ft. apart, are run in as at FG. Where FG, for instance, cuts BC, the widths of both sections must be equal, *i.e.* $ee' = ee''$. The process is continued until all the curves are fair and agree in widths. The fairness is further tested by running through a few horizontal sections. Care must be taken that the dimensions laid down in the drawing are faithfully followed, as the strength of the casting is of great importance.

The pattern maker is supplied with a skeleton mould of the profile of the frame, on which is marked the depth of the gulleting; full-size section moulds are also supplied of each arm at intervals of about 2 ft., as shown at L and S. Before parting with the mould it should be seen that the rudder can be withdrawn from the stern-post when the ship is in dry dock. In some cases this is a very neat thing, and has led to special shapes being given to the rudder to allow of this being done.

Bilge Keels.—Bilge keels (sometimes called rolling chocks) are projections fitted in the neighbourhood of the bilge to lessen the rolling motion of a ship. It is usual to fit these projections so that the centre line is in a plane which meets the middle-line plane of the ship in a straight line parallel to the L.W.L., in which case it shows as a straight line in the body. In some ships the keel aft is in a plane, intersecting the middle-line plane higher than forward, in order to reduce the resistance to forward motion, as then it is more nearly in a line with the stream-line motion in the after body. Practically all passenger vessels and warships are now provided with bilge keels.

In small cruisers, destroyers, torpedo boats, and merchant vessels, bilge keels are usually formed of a simple plate projection stiffened along the edge. This plate is either lapped on to a

T-bar or secured between two angle bars, riveted to the outer bottom. Large war vessels and liners have bilge keels of the section shown in Fig. 87, because the plate form is not strong enough on account of the depth.

The extent of bilge keel varies from one-half to three-fifths the length of the ship, it being observed that the midship portion is most effective, as it here acts with a large leverage about the centre of oscillation. The depth is usually parallel for the greater part of the length, tapered down at the ends as shown in Fig. 88. In some ships, owing to difficulty of docking, the breadth has been reduced considerably amidships. In no case should the lowest part of the bilge keel project below the keel or beyond the

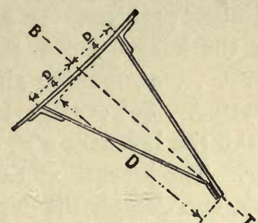


Fig. 87.

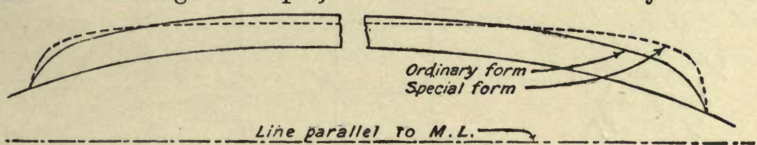


Fig. 88.

extreme breadth of the ship. Usually if the clearance when docking is small, limiting dimensions to the edge of keel are shown on the design drawings, and on no account must the bilge keel project beyond the point thus defined.

Where the bilge keel is formed of a single plate the operation of laying off the shape is simple. Let AB (Fig. 89) be the trace of

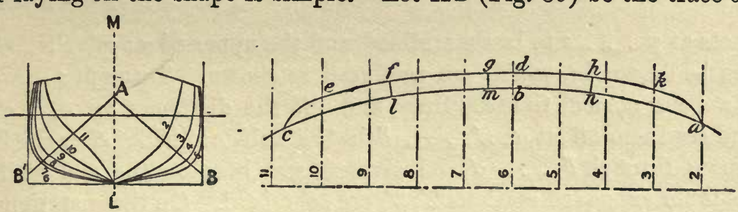


Fig. 89.

the plane of the bilge keel in the fore body. This line is duplicated on the other side. Lay off the diagonal AB to the surface of the ship, making necessary allowance for the thickness of O.B. plating beyond the frame lines. Set out from the diagonal *abc* the depth of the bilge keel square to *abc* at various places, and run a curve through these spots *efg* . . . and round the ends easily to the finishing points *a* and *c*. Check the depth amidships to see that the limiting dimension (if given) is not exceeded, and that the bilge keel does not project beyond the half-breadth. The centres of laps or butts are then placed on, as at *fl*, etc., and batten moulds are prepared for each plate for use in the yard.

The built-up form of bilge keel presents a somewhat more difficult problem. In Fig. 90, BT is the trace of the bilge diagonal in the body. Draw the diagonal in the half-breadth as before *e′d′* . . . *a′*, making allowance for the thickness of outer bottom plating. Set out the breadths and draw in the line *e′k′* . . . *f′*. Take the breadths *a′f′*, *b′g′* back to the body, obtaining points *f*, *g*, etc. The breadth at the base of the section of the bilge keel is, say, one-quarter the depth on each side of BT. This will enable

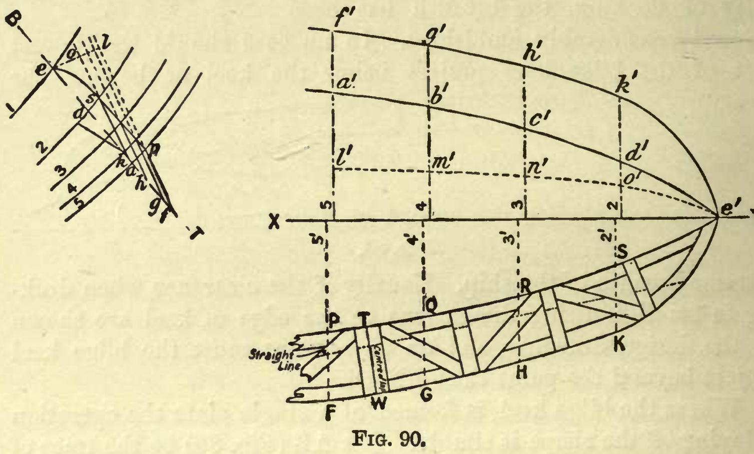


FIG. 90.

spots as *p* . . . *s* to be determined, and the upper edges *pf*, . . . *sk* can be drawn in, which are produced as shown. Through *e* draw *el* a mean normal to these lines, and lift the distances *eo*, . . . *el*, and set them off at *o′*, *n′*, . . . *l′* in the half-breadth. A curve is drawn through *l′* . . . *o′* and girthed, and keeping the end well, spots for expanded stations 2′, 3′, etc., obtained. On these stations set off distances as *lf*, *lp*, obtaining spots F, P, etc., for the outer and inner edges respectively. Curves are then drawn for these edges, viz. FG . . . K and PQ . . . S. The lower plates are expanded in the same way. Butts are marked as TW, and a batten mould made for each plate as shown.

Lining in the Trace of the Bilge Keel at the Ship.—For this purpose *erection moulds* are made. A mould as CDEF (Fig. 91) is made at the fullest section and at a section near each end of the bilge keel, the lower edges being well with the underside of keel in each case, EF fitting the O.B. plating, and FG fitting on the underside of the bilge keel trace BT. Two similar moulds are made for intermediate positions with the top battens to the upper side of BT, as shown dotted. These moulds are erected at the ship, and the battens FG made to outwind, looking over one and under the other.

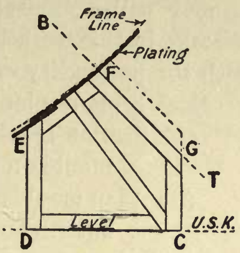


FIG. 91.

Alternative method of making Bilge Keel Erection Moulds.—Make a mould as ABCD, Fig. 91A, the upper edge AC being well with the trace of the bilge keel, the lower edge BD being well with the underside of keel XY at, say, 100 station. As the angle between AC and BD is constant, this mould may be used for other stations also by shifting along, and lifting or lowering to keep BD well with the underside of keel. For each

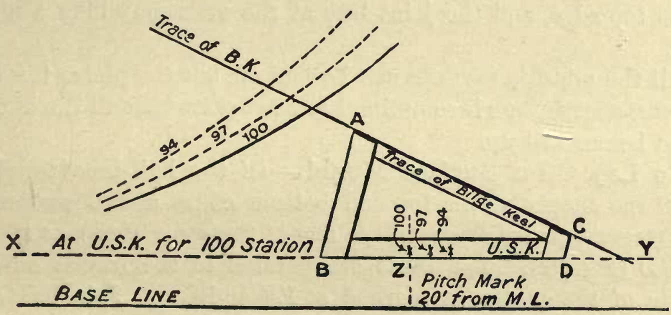


FIG. 91A.

station concerned a pitch mark is placed on BD at a given distance from the M.L. (20 ft. say).

At the ship a baseboard is erected to the U.S.K. (corresponding to XY), and the mould ABCD is erected thereon, with the pitch mark for the station concerned, 20 ft. from the M.L. A straight-edge batten is then applied to CA, and moved up until it touches the ship's bottom. By using this mould at every third station say, a large number of spots can be obtained to run in the line of bilge keel.

Sections for cutting timber for filling can be supplied from the floor for the information of the sawmills, about 6 or 8 ft. apart, which enables this wood to be rough-cut in advance.

Armour Moulds.—Perhaps the most important set of moulds issued from the loft floor are those for the armour, giving the shapes to which the armour plates have to be manufactured. Great care is necessary to obtain good results in order that the armour will accurately fit the ship when erected in place. A mistake in this work is likely to result in considerable expenditure with the possibility of serious delay.

Each armour plate requires nine moulds, viz.:—

(i.) Section moulds for each end of the plate with outwinding moulds for each;

(ii.) Plan moulds of the top and bottom edges with companion outwinders; and

(iii.) A surface mould.

The sections for the ends of one plate are made to serve for the next plates before and abaft.

Generally speaking, the lower edge of armour is horizontal, as also the joint line over the midship portion. The sheer is followed by the top edge, and the joint line at the ends may take a mean sheer.

All the midship portions can be laid off, but the plates towards the ends, where there is sometimes some curvature in all directions, should be mocked up.

To Lay Off a Surface Mould.—In the half-breadth plan, lay off the shapes of the top and bottom edges of the particular plate (several plates are usually done at the same time), as at AB and CD (Fig. 92). The butts are parallel to the frames on the outside of the plates, as marked at EF and GH. Join EG, and through the middle point K draw a line KQ′ square to EG. Also through M′ and O′ where EG cuts the stations next to the ends of plate, draw M′N′ and O′P′ parallel to KQ′. Girth the frames 2 and 5 in the body plan, allowing a clearance from the top of recess (say, $\frac{1}{4}$ in.), and set out these distances at M′N′ and O′P′. Girth the plan of the top FQH, marking the point Q where KQ′ cuts CD. Keep Q well with Q′, and expand the top edge along N′P′ to F′ and H′. Ascertain if there is any difference in girth between the curved line EG and the straight line EG, expanding, if necessary, about K. Join EF′ and GH′. Then EF′H′G is the developed shape for the surface mould.

The plan moulds are made to the curved lines EG and FH. The surface of the butts are in a double-canted plane, which is at a mean normal to the curves of the plan moulds. In Fig. 93 *ae* and *bf* are the plan lines corresponding to EG and FH (Fig. 92), and *ab* and *ef* are the outside edges of the butts. Draw *ac* and *bd* parallel and at a mean normal to the curves at *a* and *b*, and similarly at the other end. Then *cg* and *dh* are drawn the thickness of the armour in from *ae* and *bf*, and *aegc* and *bfhd* are the plan moulds. Two parallel lines, *kl* and *mn*, are drawn a convenient distance from *ae* and *bf*. Then *kael* and *mbfn* are the outwinding moulds. Similar moulds are made for each end of the plate from the body-plan sections, allowing the necessary clearance at the top. For the midship plates it is advisable to

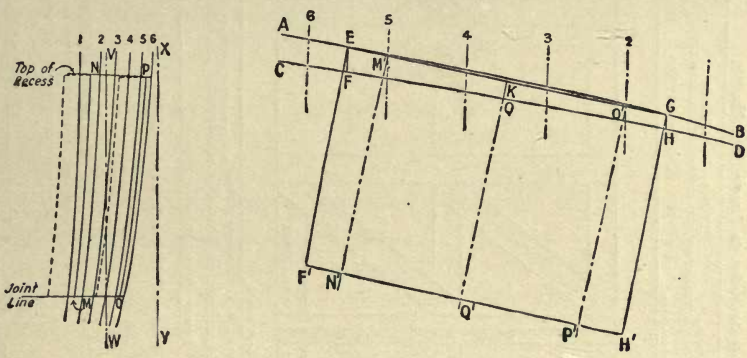


FIG. 92.

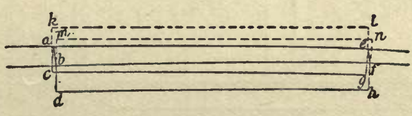


FIG. 93.

have the outwinding edges to vertical lines, as VW and XY, so as to enable the moulds to be conveniently used for the next plates.

It is essential that the widths at the ends of the plan moulds should agree with the corresponding widths of the section moulds. Also that the lengths of the plan and section moulds along the edges of the plates should agree with the corresponding edges of the surface mould; this can be tried by rolling the curved edges of these moulds along the corresponding edges of the surface mould.

A specimen set of moulds prepared as above is given in Fig. 94, with the various notes that are placed upon them. All moulds have a straight line marked on them for checking purposes, and also a line 1 in. from each edge, for use in the event of the edge being damaged.

Sometimes the side armour is so disposed that each armour plate is arranged to be perfectly flat and as nearly as possible

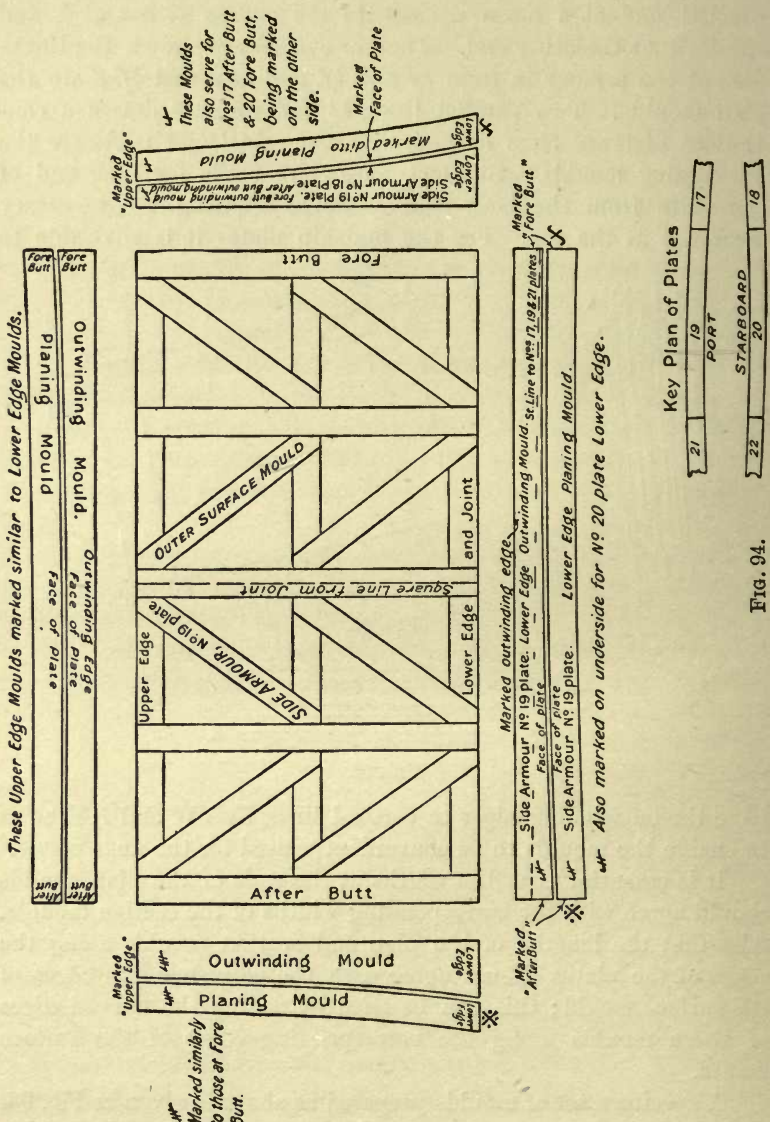


Fig. 94.

rectangular in shape, so as to facilitate the manufacture. In this case, the edges and butts of armour on the outside surface will form a series of knuckles.

Mocking up.—A surface which has curvature both ways is *undevelopable*, and by no direct process of geometry can the true shape or area be obtained. The outside surface of a ship, for the most part, is such a surface. To solve various problems and to obtain correct moulds for different parts connected with this surface, we have to resort to the process known as *mocking up*.

Mocking up is employed to determine the shape of the surface moulds for armour at the ends of a vessel, for outer bottom plating having excessive twist and curvature, and for any case where two curved surfaces meet. The process is often employed in some extreme cases where a surface can be laid off, *e.g*. a longitudinal having a good deal of twist, or the stern plating of a merchant vessel.

Mocking up, as the name indicates, is the process of duplicating the particular portion of the vessel on the floor, by means of rough frames and sections, so that the necessary moulds may be made as though they were being fitted to the ship. The framed moulds are termed *horses*, and are usually made to the true shape of the intersections with the ship by a series of planes, such as square stations in the body plan, and bow and buttock planes in the sheer or cant frames in planes perpendicular to the half-breadth. The horses are then built up in their true relative positions, and we have a *mock* ship on which the fabric of the moulds required may be constructed.

Note.—It may be rapidly determined that a surface is approximately developable as follows: If in any direction on the surface the intersections of the surface with any series of parallel planes appear as straight lines, then the surface is part of the surface generated by a rolling cylinder (if the straight lines projected square to the parallel planes appear parallel) or by a rolling cone, right or otherwise. Such a surface can be developed by the method of the longitudinal (p. 64). In this case the series of parallel planes are the square stations on which the traces of the intersections with the longitudinal surface appear straight. Before development the whole must be projected on to one of the planes.

To Mock up a Longitudinal.—In Fig. 95, 1, 2, etc., are the inner and outer bottom frame lines, AB and CD being the respective sight edges of the longitudinal. The twist is shown by the angle between AC and BD. A convenient base line XY is drawn below the traces about parallel to the mean line between AC and BD, and so that the highest point of a trace (say B) is about 4 ft. above XY. A horse is made between each trace and the base line, and on each is marked the edges of the longitudinal (allowing for the raised strake of plating), and also the position of the line SL, which is square to XY, which serves as a plumb line when erecting the horses. The horses are then erected in their correct relative positions, as shown in the half-breadth, each being pitched so that the marks at SL are all in a vertical fore and aft plane, which plane cuts the floor in the straight line S′L′. The

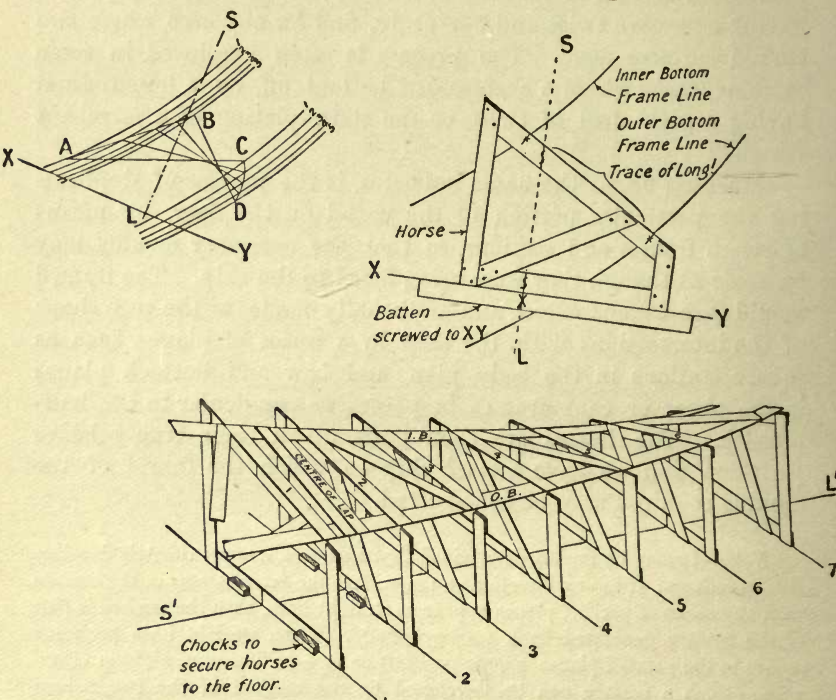


Fig. 95.

horses are carefully squared up, spaced, and stayed, being checked by penning a batten through the spots representing the longitudinal edges. The surface mould is then constructed as shown.

It is desirable, when constructing the horses, to fix a batten beneath the line XY as shown, rather than pitching the lower batten of the horse each time to the base line. This is not only quicker, but more accurate. The method described above is considered to be less cumbersome than that of using the permanent horses kept in some yards for the mocking up of longitudinals.

Mocking up Armour Moulds.—Horses are made to the outside of the armour plate and to a convenient base line inside the body plan. The mock up requires very careful testing as the long horses twist and sag. The spacing must be quite even and the surface fair. Surface moulds are made as already described. Outwinders are made at the butts and section moulds made from these.

Mocking up the Stern Plating of a Merchant Vessel.—This plating is mainly supported by means of cant frames, the true shape of which can be obtained by rabatting on to the sheer or body. Horses are made to these cant frames down to a horizontal base, and these are then erected on the plan lines in the half-breadth, Fig. 96.

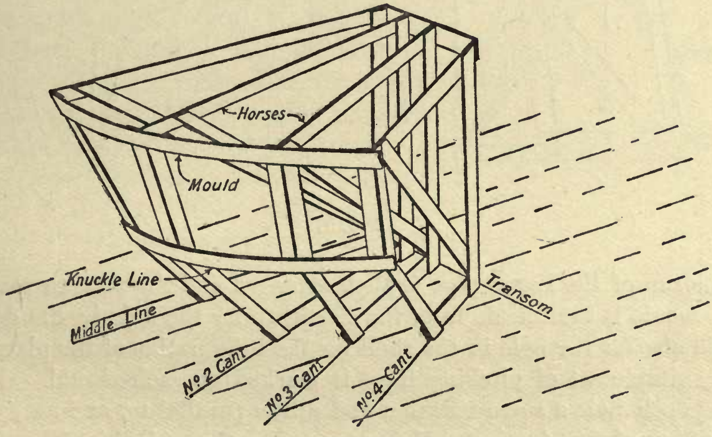


FIG. 96.

Mocking up for an Outer Bottom Plate having excessive Curvature or Twist.—Such plates are those which come on the stern-post or the bossed plates round the shaft swell. In this case horses are made to the frame lines *on the outside* (Fig. 97) so that the mould comes on the inside and will therefore apply on the inside of the outer bottom plate. Fig. 97 shows the construction of a cradle mould, with a flange at the end for connection to the stern-post.

Moulds for Holes in Deck and Side in way of Hawse Pipes.—The large bell-mouthed hawse pipes used for stockless anchors have to be mocked up to obtain the correct shape for making the pattern. When a novel type of anchor has to be dealt with, it is necessary to experiment first with a model of the fore end of the ship and a model anchor. To mock up full size, sections are made from the body plan, between the frame line, beam line, and a convenient level line for the stations affected, and these are erected in their proper relative positions in the pattern shop.

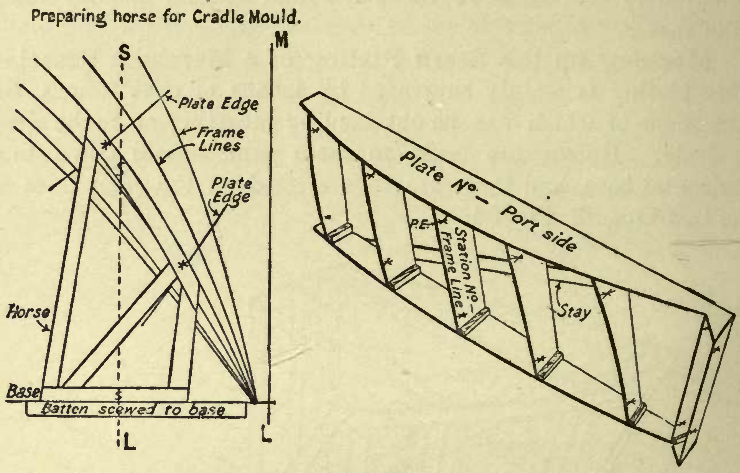


Fig. 97.

The run of the hawse pipe is then arranged and the pattern made. A mould is then made from the mock up for the hole in the deck and also for the hole in the shell for the information of the platers. A suitable set of pitching lines is marked on each mould. For the deck hole a square station and a line parallel to, and an even number of feet from, the M.L. are used as shown in Fig. 98. For

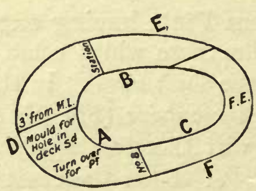


Fig. 98.

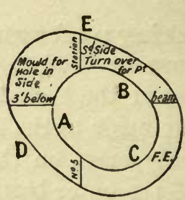


Fig. 99.

the side hole a line parallel to the beam at side measured along the run of the frames and a square station are used as shown in Fig. 99. In Figs. 98 and 99 ABC is the hole in the plating and DEF the outside of the flange of the hawse-pipe casting.

Davit Moulds.—An outline mould of the curve of davit is prepared for the information of the smith, as Fig. 100. This is simply a full-sized reproduction of the detail sketch. It is as well to girth round the centre line of davit and spring out on a straight line and fair a line through the critical dimensions as at the head, bow of davit, and upper bearing. These are taken back to the curve of centre line of davit and the inner and outer outlines run in.

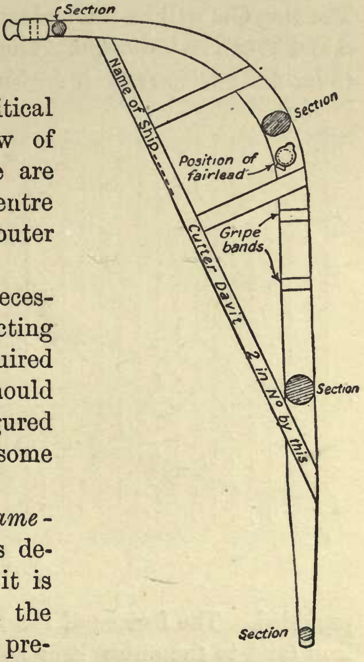


FIG. 100.

Lifting Battens.—All the necessary information required for erecting and keeping the ship to the required form should be sent out from the mould loft on *battens* rather than by figured dimensions. The following are some of the battens frequently required.

Keel-lifting Batten and Frame-lifting Batten.—When a vessel is designed with a trim by the stern it is usual to keep the L.W.L. level in the body so that the underside of keel presents a series of parallel lines, and the frame lines a series just above them. The distance that these lines are above or below the base line is termed the *lifting*. Owing to the closeness of these liftings for consecutive frames, it is practically impossible to scratch them in clearly on the floor or scrive board, and so a batten is prepared for reference. On a series of very much contracted stations (which may be drawn on cartridge paper or a board, on a scale, say, of $\frac{1}{8}$ in. = 1 ft.[1]) draw a line XY (Fig. 101) to represent the base line. At A the midship frame set down the thickness of the two keel

[1] For such work as this, a special board has been introduced at Chatham. The board is 12 ft. long, 6 ft. wide, and 1 in. thick, thoroughly stiffened and raised on trestles 2 ft. high. The surface is black and is divided along its length into parallel lines 2 in. apart; there are four equally spaced lines square to these for base lines. There are light battens of pitch pine and ordinary draughtsmen's weights for working. The board is used for all manner of contracted work, such as fairing deck sheers, plate edges, inner bottom, sight edges of longitudinals, etc.

plates to B. On FP and AP set up or down the points C and D so that a line joining them passes through B and the vertical distance between C and D gives the trim in the length between perpendiculars. The line CD will be the underside of keel, and the points of cut up, S and T, can be indicated. The various thicknesses of the outer and inner flat keels are then drawn in as shown from the information

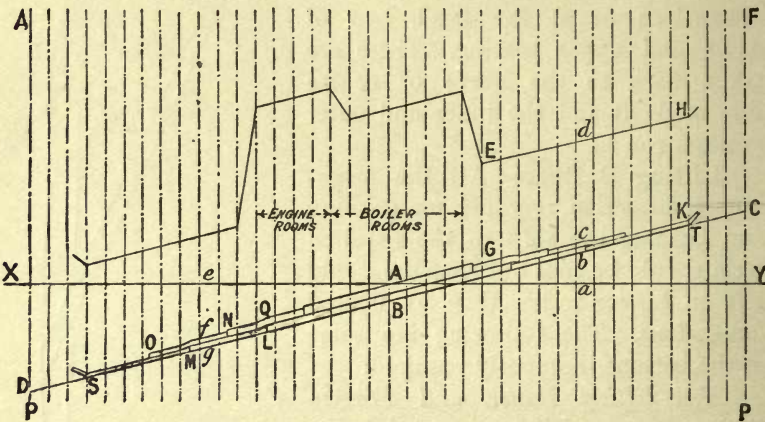


FIG. 101.

provided. The frames of the vessel fit *well* to the top of the inner keel (and to the outer keel at the ends), and if each distance as *ac* and *ef* is recorded on a batten above or below a pitch mark representing the base line, we have a *standard frame-lifting batten.* Similarly distances as *ab* and *eg* marked on a batten from the base line will form a *standard underside of keel* (*U.S.K.*) *batten.* One of each of these battens should be supplied to the scrive board and one of each kept in the loft.

A batten showing the distances of U.S.K. from the L.W.L. is found very useful for the liner-off at the ship.

Top of Vertical Keel Batten.—The depth of the vertical keel along various portions of the length is usually specified, but if these depths were set up from each frame lifting we should have every variation of the keel thicknesses reproduced along the top of the vertical keel. Referring to Fig. 101, if for the stretch of the vertical keel EH, the depth specified is set up at each end as GE and KH, then EH is an average line and the inner bottom (or tops of floors) will be fair along the middle line. A batten is prepared showing such distances as *ad* above the base line.

Longitudinal Lifting Batten.—For checking the form of the ship a batten showing the height of the root of each lower longitudinal angle bar above the underside of keel (at every third station, say) is supplied.

The lines scratched in on the body plan for the trace of a longitudinal is the line BA, Fig. 102. The longitudinal bar will come below the frame line an amount equal to the mean thickness of the adjacent outer bottom plates. The height required at the ship

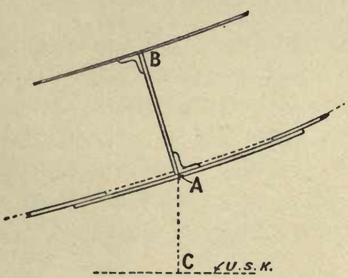


FIG. 102.

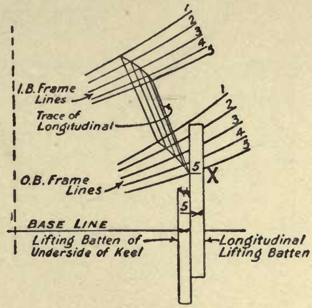


FIG. 103.

is that of A above the U.S.K. as AC. To prepare the batten, take for example the frame marked 5 in Fig. 103. Lay the U.S.K. lifting batten with its pitch mark on the base line and place the longitudinal lifting batten with its pitch mark against the required frame number. Then mark as shown at X, the height of the intersection of the trace of the longitudinal with its frame, making the necessary allowance for the thickness of the sunken strakes.[1]

Various Battens.—Besides the battens and moulds mentioned above, the ship is supplied with such battens as *heights between decks, lengths of pillars, centre of shaft, spreads of frames*, etc., all of which can usually be marked directly from the body plan. Also particular moulds which may be required by the special ship being built are provided, such as rough curves of deck edge (for cutting waterway planks before the deck is erected at the ship), breasthook moulds, mast tube expansion moulds, etc., etc., and also any bevellings of boundary and other bars as the necessity arises.

[1] Some scrive-board workers adopt the principle of working "thickness up"; *i.e.* the thickness of the longitudinal plate is allowed on the upper side of the line copied from the mould loft floor. Where there is not a definite understanding between the scrive board and the floor, it may possibly lead to mistakes. The thickness of plate must be allowed where the lower angle bar of the longitudinal is on the upper side.

As already stated, there is a growing practice of preparing moulds on the loft floor rather than in the shipyard. Greater accuracy is obtained in this way and the rapidity of the work is facilitated. In ships of constant section throughout the length, the design is so arranged as to allow of standard moulds being employed, which may be used over and over again for marking off, as *e.g.* for the edge riveting between frames, butt-straps, etc.

CHAPTER VI

MISCELLANEOUS PROBLEMS

To take off the Plank forward and obtain the "Bearding Line."—The "bearding line" is the intersection of the moulded or frame surface of the ship with the stem, keel, and stern-post, the intersection of the outer surface with these being termed the fore edge, bottom or after edge of rabbet, as the case may be.

In Fig. 104 the shape of the ship forward is defined by the full lines, the line *bc* being the fore edge of rabbet. Up to the stem

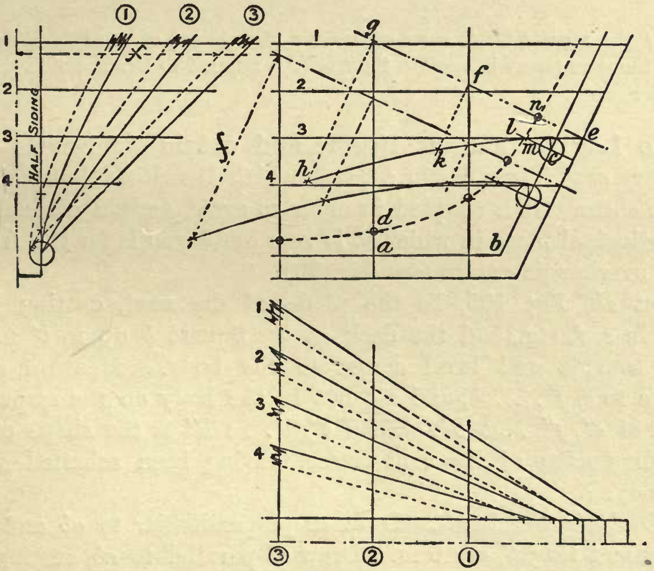


FIG. 104.

the plank is taken off in the manner described in Chap. III., resulting in the dotted moulded surface, and the problem is to find the ending of this surface at the keel and stem. There is no difficulty at the keel. A circle is struck in at the lower edge of rabbet in the body, of radius equal to thickness of plank, and the frame-lines are ended as tangents to this circle as shown. The intersection of these lines with the half-siding are squared across to the sheer as at *d*.

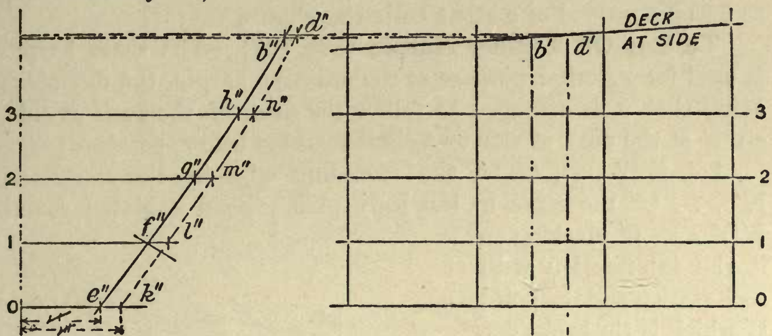
Take normals to the stem contour as *efg*, cutting stations in points as *f* and *g*, and draw normals *gh*, *fk*, etc., equal to the breadths at the height of *g* and *f*. From *ef* set out the half-siding of stem at *cl*, and from *c* where fore edge of rabbet squared out meets *cl*, draw a circle having a radius equal to thickness of plank. Then a curve through *hk* is finished as a tangent to this circle, meeting the rabatted half-siding in *m*. This point is then squared back to *n* on the normal *ef*. Then *n* is a point on the bearding line, and doing similarly for other sections as shown the curve *d* . . . *n* is drawn in, which is the bearding line. The points where this line meets the level lines are squared down to the half-siding in the half-breadth, and the dotted lines are ended there as shown.

For the more difficult cases where the stem is not of parallel siding, and where the stem tapers in breadth the reader is referred to Dr. Thearle's "Naval Architecture."

To Lay Off a Cant Frame and obtain its Bevels.—An ordinary cant frame lies in a plane which is vertical but inclined to the sheer. It is adopted in order to avoid excessive bevelling. The principal place in which it is now employed is for the frames to an overhanging stern (see Fig. 96).

Let *ab*, Fig. 105, be the plane of the cant, cutting level lines in *e*, *f*, etc., and the deck at *b*. Square *b* up to *b′* to the deck at side and level across to the body. Measure along from *a* to *e*, *f* . . . *b*, and set out in the body on the respective levels at *e″*, *f″* . . . *b″*. Then *e″f″* . . . *b″* is the shape of the moulding edge of the cant frame, having been rabatted on to the body.

To obtain the Bevels.—Draw *ac* perpendicular to *ab* and of a convenient length, say 6 in. Draw *cd* parallel to *ab*, cutting the level lines in *k*, *l* . . . and the deck in *d*. Rabat *cd* on to the body about the point *a* in a similar manner to the above, obtaining the curve *k″l″* . . . *d″*. Then the bevel at any point as *f″* is the square distance from the dotted line taken on a base equal to *ac*. (Note that a bevel is always taken square to the frame, so that it is the square distance that is required, and not the distance $f''l''$.)



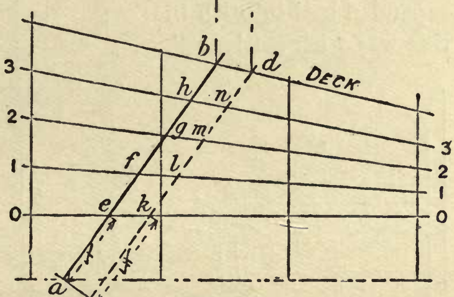


FIG. 105.

To Lay Off an Ordinary Harpin and obtain its Bevellings.—An ordinary harpin lies in a plane which is square to the body but inclined to the sheer. In Fig. 106 $a''b''$ is the moulding edge of such a harpin. The plane is rabatted on to the half-breadth, and this involves the same process as that of laying off a cant frame. The bevelling edge shown dotted *glkh*

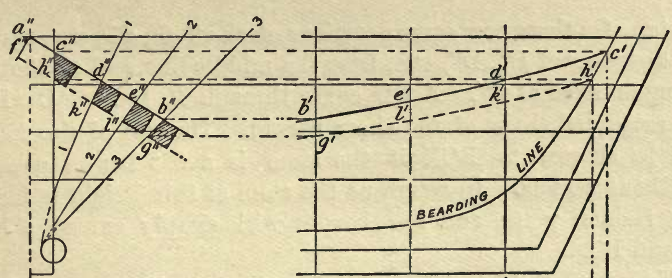
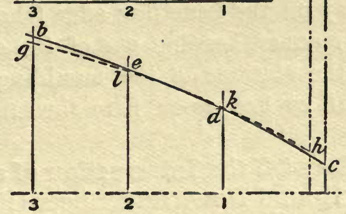


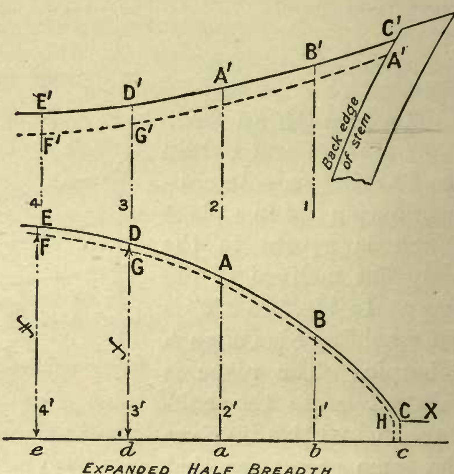
FIG. 106.



is similarly obtained. The bevel will be "in" or "out" according to whether the bevelling edge is outside or inside the moulding edge. The sections of the harpin have been shown in exaggeration to show up the bevels, observing that angle bars are often used as harpins instead of a stout batten as shown.

To Lay Off a Sheer Harpin (Fig. 107).—The sheer harpin is used for a similar purpose as the ordinary harpin, the difference being that it is arranged to follow the sheer of the deck at side, either at the deck at side or a short distance below, parallel to it.

Let E′D′ . . . C′ be the moulding edge in the sheer and E″ . . . C″ the same in the body plan. Bend a batten round E′D′ . . . C′, marking on it the intersection with each station and the point C′ which is the back edge of the stem. Obtain an expanded half-breadth in this way with stations 4′,



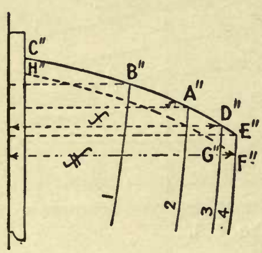


FIG. 107.

3′, etc. On these new square stations mark off *e*E, *d*D, etc., equal to the distances of E″, D″, etc., from the middle line, and *c*C the half-siding of stem at C″. A fair curve through E, D . . . C will be the expanded shape of the sheer harpin. The end of the harpin will be shaped to BCX if the stem is a flat bar as usual in merchant vessels. In warships the stem at this height is formed of a fashion plate, and the harpin will simply extend a little beyond BC.

To lay off the bevelling edge (shown dotted) we proceed in a similar manner, keeping one of the expanded stations well with one of the stations of the moulding edge. Unless the form is very bluff or has much flare the same stations will do for both edges.

To Lay Off the Intersection of a Single Cant with a Deck having Round Down and Sheer (Fig. 108).—Let *cd, c′d′* be the deck at side in half-breadth and sheer respectively, *a′e′* being deck at centre, and A″C″ the beam curve. Let *ab* be the plan of the single cant; *a′* and *b′* are evidently two points on the elevation of

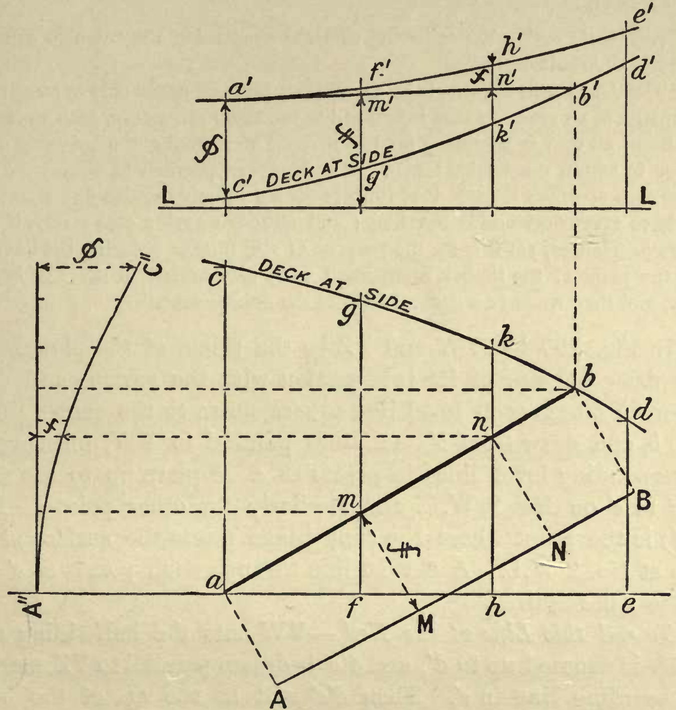


FIG. 108.

the intersection. Take the point *n*. The distance *h′n′* will be the round down in the half-breadth *hn*. Thus points as *n′* and *m′* may be obtained and the vertical projection of the intersection *a′m′n′b′* drawn in. Draw a level line as LL and take off heights of *a′*, *m′*, *n′*, and *b′* above this line. Draw *b*B, *n*N, etc., perpendicular to *ab* and equal respectively to these heights. Then a curve through AMNB will be the true shape of the intersection.

The above is the method of working out the following problem:—

To find the true length of a diagonal tie plate which crosses a deck having round down and sheer.

Problems similar to the above.

To lay off the intersection with a deck having round down and sheer of—

(1) *A plane which is square to the body plan but inclined to the half-breadth*;

(2) *A plane which is square to the sheer but inclined to the half-breadth.*

To determine the True Shape of the Intersection of a Plane inclined both to the Sheer and Half-breadth with the Surface and Deck of a Ship.—This is the problem of the *double cant.*

Dr. Thearle makes the following remarks concerning the "double cant" in his "Naval Architecture":—

"The *double cant* appears to be an abstract problem useful only as an exercise. The plane of an ordinary cant is inclined to the sheer plane only, such an inclination being all that is necessary for the purpose of reducing the bevelling of the timber to within practicable limits. It is, however, possible to conceive a ship, the surface of which is such, that timbers canted in only the one direction would still have very considerable bevelling; and although such a case rarely, if ever, occurs in practice, yet it is for the purpose of still further reducing the bevelling that the plane of the timber is supposed to be also canted to the half-breadth plane, and then we have a general form of the double cant."

In Fig. 109 let VW and YZ be the traces of the plane. We first draw the v.p. of its intersection with the surface and deck. Where YZ cuts each level line square down to the centre line as b' to b, and draw from b', etc., lines parallel to VW, meeting the corresponding level lines in points as c. Square up to the sheer as c to c' on No. 2 W.L. and similarly for other points. Then (c, c') is the point where the cant plane meets the surface of the ship at No. 2 W.L. A curved line through such points as c' will be the v.p. required.

To end this Line at the Keel.—VW cuts the half-siding at d, which is squared up to d', and $d'e'$ is drawn parallel to YZ, meeting the bearding line in e'. Then $d'e'$ will be the v.p. of the intersection of the cant plane with the side of the keel, and the curve through c', etc., will end at e'.

To find the v.p. of the intersection of the cant plane with the deck, we draw bow lines in plan and elevation as A, B; A′, B′. The intersection of the cant plane with B bow line, say, is found by squaring up k to k' and drawing $k'l'$ parallel to YZ, meeting B bow line in elevation in l'. Then l' is the intersection required, and a curve through such points as l' will be the v.p. of the intersection of the cant plane with the deck.

To find the True Shape of the Intersection—Rabat the cant plane about its vertical trace YZ on to the sheer. Take the point (c, c'). In rabatting c' must move perpendicular to YZ. Therefore draw c'C perpendicular to YZ. The true length of $(bc, b'c')$ is given in plan, viz. bc. Therefore, with centre b' strike an arc of radius bc, cutting c'C in C, and so on for other points. Similarly

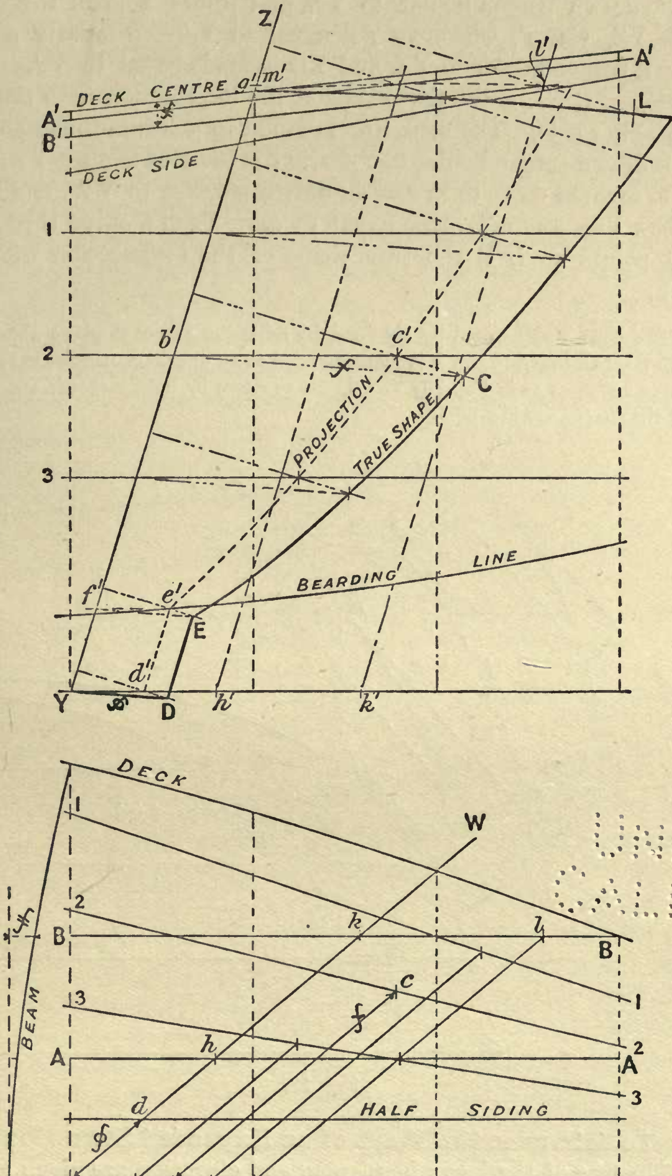

Z
l'
A'
DECK CENTRE
o' m'
L
A'
B'
DECK SIDE
1
2
3
b'
c'
C
PROJECTION
TRUE SHAPE
BEARDING LINE
f'
e'
E
d'
Y
D
h'
k'
DECK
W
1
2
3
B
k
l
B
1
c
2
BEAM
A
h
A
3
d
HALF SIDING
V
h
m

FIG. 109.

e'E is drawn perpendicular to YZ, and where a level through e cuts YZ, viz. f, we draw fE equal to Vd. Similarly d'D is drawn perpendicular to YZ, and YD is made equal to Vd. Then YDE . . . C . . . is the true shape of the intersection with the keel and ship's side. The deck line is found in a similar manner, viz. l'L is drawn perpendicular to YZ, and l' is levelled to meet YZ in m'; m' is squared down to m and ml drawn parallel to VW, ending at B bow line, and m'L made equal to ml. Then a curve through g' and points as L is the true shape of the intersection with the deck.

The same result would be obtained by rabatting the cant plane about VW on to the half-breadth, and it is recommended as an excellent exercise in drawing to take a surface as in Fig. 109, and do the problem by both methods and seeing that the shapes are identical.

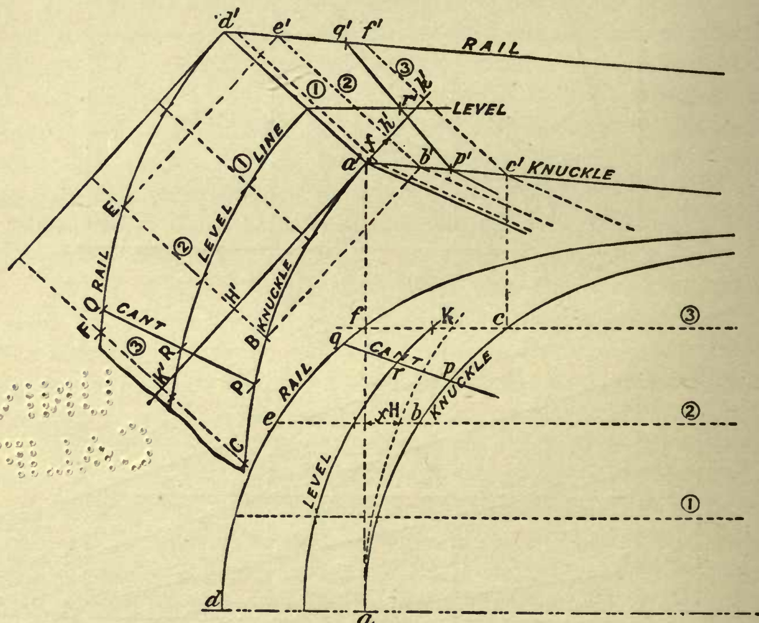


FIG. 110.

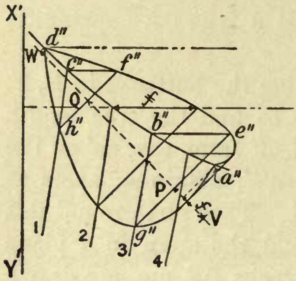
To determine the Shape of an Expanded Stern (Fig. 110).—The line of the knuckle in plan and elevation are given on the design drawings, as also the slope of the stern $a'd'$. The stern plating is usually a cylindrical surface with the generators of the cylinder parallel to the middle line. Therefore, square up the intersections of the buttocks with the knuckle as b, c to the sheer at $b'c'$, and draw $b'e'$, $c'f'$ parallel to the slope line $a'd'$ and equal to it. This enables the sheer line of the rail to be drawn in, and points as d', e', and f' are squared down to the middle line and the corresponding buttocks at d, e, and f, giving the plan of the rail *def*. Then we have to unwrap the surface of the stern to obtain its shape, and the shape being cylindrical a true development is possible.

Draw $a'h'k'$ perpendicular to $a'd'$ cutting the buttocks in h', k'. What we want, to unwrap the stern, is to find the true length round the stern from a' to h', k', etc. Set off from, say, aa' on the various buttocks distances equal to $a'h'$, $a'k'$, obtaining spots as H and K, and draw a curve through *a*HK. Then girth round this curve and we obtain the true length round the stern in a plane perpendicular to $a'd'$. The expanded buttocks BE, etc., are drawn as shown parallel to $a'd'$; a'H$'$, for instance, equalling the girth *a*H. Points as e' and f' are projected to E and F, and points as b' and c' to B and C. The curves FEd' and CBa' will then determine the true shape of the stern from which the plating may be ordered.

In order to arrange the butts of the plating it will be necessary to show on the cant frames which are usually inclined to the middle-line plane. This presents no difficulty and is left as an example, the figure showing how the cant in plan *pq* becomes PQ on the expanded stern. A level line is necessary as shown, in order to determine the line PRQ, which, although practically straight, is not absolutely so.

To Lay Off a Sponson Plate.—It is often necessary to arrange a local extension of a deck over the ship's side for the purpose of obtaining the support for a gun, searchlight, or other fitting. In Fig. 111 *aed* shows such an extension beyond the deck line *abd*. The support is usually arranged by means of a sponson plate taken from the edge of the projection to the ship's side. This is preferable to supporting by means of stanchions or brackets, as the blows of the sea are deflected outwards. It is desirable to form the sponson plate so that it can be *rolled;* it should therefore be a developable surface, and this condition is obtained by making the sections in any one set of parallel planes straight lines.

Let *abd*, $a'b'd'$, $a''b''d''$ be the beam at side in the half-breadth, sheer, and body plan respectively, and *aed* the extension of the deck in the half-breadth. XY and X$'$Y$'$ are a convenient distance from the middle line. The extension is taken to the body as shown, giving the projection of the outer edge of sponson in the body $a''e''d''$. The general shape desired for the lower edge of sponson plate will be furnished to the loft; usually the lowest point as g' will come at the same station as the broadest part of the extension. Project g' to the body at g'' and join $g''e''$. Through



points as f'' draw lines parallel to $g''e''$, meeting the sections in points as h''. Pass a fair curve through $d''h''g''a''$ and project these points on to the sheer, when a pleasing line should be obtained, $a'g'd'$.

We now proceed to develop the sponson plate as follows: Draw a line VW perpendicular to $e''g''$, etc., and find the shape of the intersection of this diagonal with the lines $f''h''$, etc., using a pitching spot as V, obtaining the dotted curve pq in the half-breadth. Girth round this path and obtain expanded stations 1′, 2′, etc. Measure the distances of the points as a'', e'', g'', etc., above and below the diagonal line VW in the body and set off on the expanded stations as shown. Pass curves through AEFD and AGHD, which will give the expanded sponson plate. Additions are made as necessary for connecting flanges.

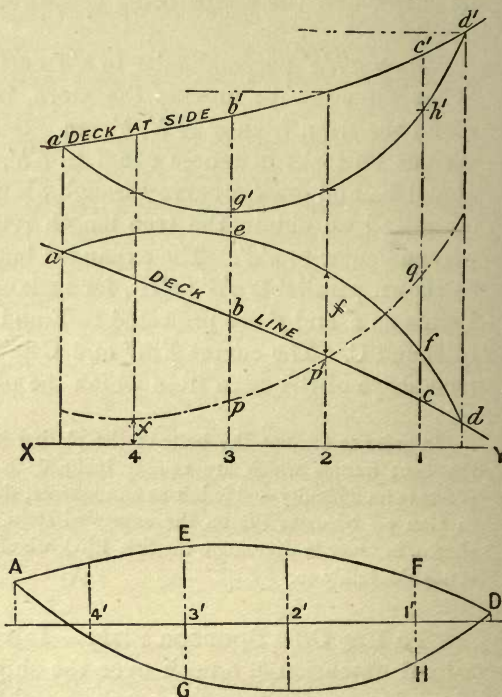


FIG. 111.

Notes.—

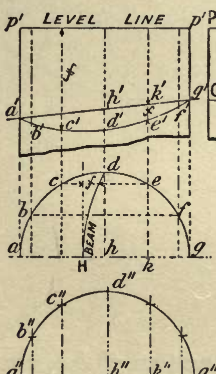
(1) If the deck has no sheer, then the spots are on a level line in the body plan.

(2) In the above example the extension is level. If it is desired that the beam curve should be followed, then the points as e'' must be set out on a beam round curve continued through b'', the beam at side for that station. Otherwise the process is the same.

(3) If some of the stations affected come in the opposite body they should be transferred, and in some cases it may be necessary to introduce half stations.

Problem.—A circular barbette pierces the curved side of a ship, from the lower deck upwards. The outside of the ship below the barbette is finished by means of a sponson plate. Show how to determine the profile view of the line of intersection of the barbette and the sponson with the side of the vessel.

A Circular Barbette pierces a Deck having Round-up and Sheer. Determine the Development of the Portion of the Barbette above the Deck (Fig. 112).—Let $a'g'$ be the deck at middle, adg the half plan of the barbette, and dH the beam curve, the level top of barbette being $p'p'$. Divide the circumference at



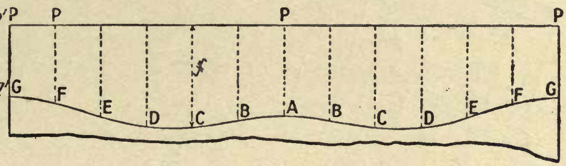


FIG. 112.

points f, e . . . b, and square up to the sheer and across as shown. Set down from the deck at middle, distances as $h'd' = h$H, $k'e'$ = round down in half-breadth ke. A curve through $a'b'$ . . . $e'g'$ will be the elevation in the sheer of the intersection of the barbette with the deck. Draw a level line PP and divide it into portions equal to the divisions made in the circumference, PP being equal to the whole circumference. Draw the dotted lines, and from PP set down G, F, etc., equal to the distances of g', f', etc., from the level line of the top of barbette. Then a curve through GF . . . A . . . G will be the developed shape of the intersection of the barbette with the deck.

To develop the hole in the deck we need to develop in both directions. Pen a batten along the deck at centre $a'g'$, marking a', g', and spots as h', k', and set out the longitudinal expansion as in the lower figure at a'', h'', k'', g''. Draw square lines through these points and mark off the girth round the beam line to corresponding breadths, obtaining points as c'', d'', etc. The curve $a''b'' \ldots g''$ will then be the developed shape of the hole on one side, and this can be repeated for the other side.

EXAMPLE.—Work out the above problems for the case when the centre of the barbette is not on the middle line.

To find the Development of the Heel of a Raking Mast on a Deck which has both Round and Sheer (Fig. 113).—The mast is drawn as shown with centre line *ab* and diameter *ef*. Draw a semicircle *ekf* and divide up in the points *g*, *h*, etc. The

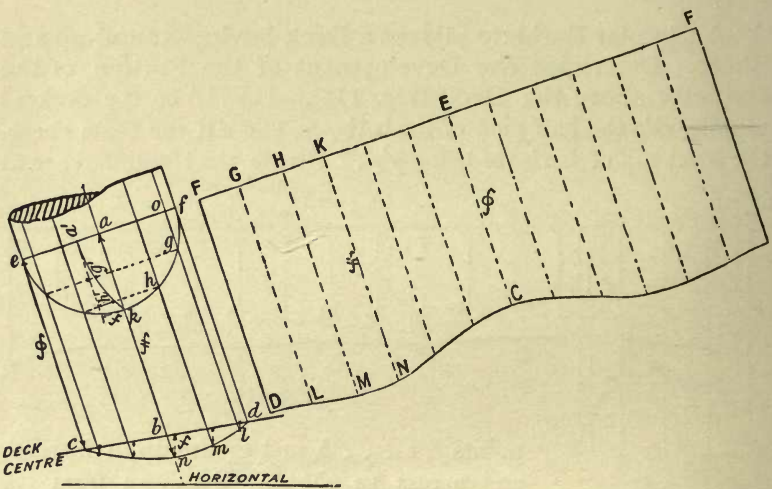


FIG. 113.

beam curve is drawn in *a'k*. Draw in the generators *gl*, *hm*, etc. The round down in the breadth *g* is set down *vertically* from the deck at centre to cut the generator through *g* in the point *l*, and so on for the points *m*, *n*, etc. A curve $c \ldots mld$ will be the elevation of the intersection of the mast with the deck. To develop, draw FGH . . . F and make divisions equal to the girth of the mast, *i.e.* FG = *fg*, etc. Then make FD = *fd*, GL = *ol*, etc., and draw a curve through points DLMN, etc., which will determine the shape of the lower portion of the mast.

EXAMPLE.—Work out the above problem for the case of a mast strut not at the middle line.

To develop the Bottom Plate of a Raking Tapered Mast. when the Deck has Round Down and Sheer (Fig. 114) —Let AB be the centre line of mast and CD the deck at middle.

Draw any two diameters EF and GH, and on them describe semicircles and divide these into the same number of equal parts, as *e, d, c* . . . and *l, k, h* . . . Project these spots on to the diameters and draw in the projections of the generators 1, 2, 3, 4, 5. Planes square to the middle-line plane through these lines will contain

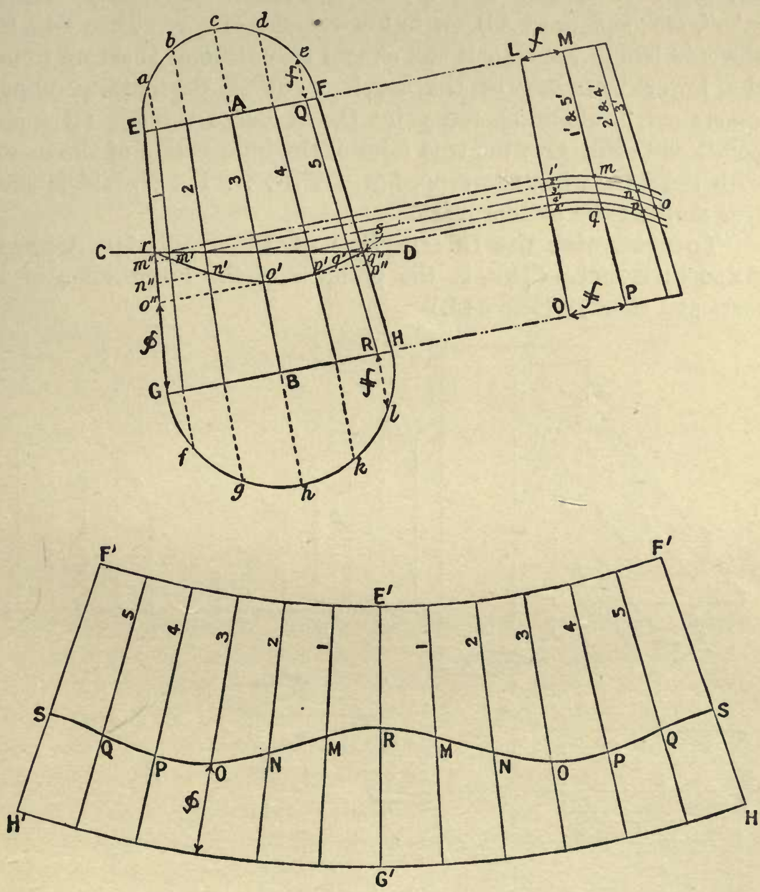


FIG. 114.

these generators. Suppose such planes to exist, and get their side elevation as in the right-hand figure. LO is parallel to AB, and LM = *e*Q and OP = R*l* for 1 and 5, and similarly for the others. Draw the intersections of the deck with these planes with 1′ . . . 5′ as shown and pick out corresponding intersections, as

m, n, o, etc., and project these back to m', n', o', etc. A curve through r and s and these spots will be the projected form of the lower edge of the mast in the sheer plan.

Expand the surface of the truncated cone, as shown in the lower figure, by one of the methods given in Chap. I. (The curvature of H′G′H′ and F′E′F′ cannot be neglected.) Draw $m'm''$, etc., square to AB on to the side generator. Then Go'' is the true length between B and o', and this distance is set up from the lower boundary of the development at the corresponding generators 3, obtaining the point O. A curve through all such points as O will give the true form of the intersection of the mast with the deck when unwrapped, and F′S . . . R . . . SF′ is the *true shape* of the bottom plate.

To determine the Intersection of Two Cylinders whose Axes intersect.—(This is the problem of the intersection of a mast and strut.) (Fig. 115.)

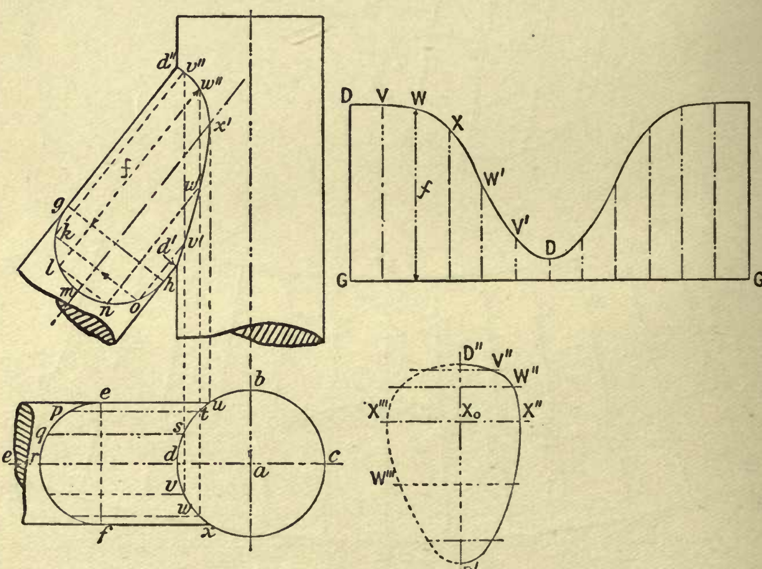


Fig. 115.

Divide the circumference of the strut in points as p, q, etc., and draw the generators in plan, pt, qs, etc. Draw these generators in elevation; kv'' and ov' will correspond to qs in plan and lw'' and nw' will correspond to pt in plan, mx' the centre line in elevation will correspond to eu in plan. Square up t to w' and w'', u to x',

s to v' and v''. Then a curve through $d'v'$ . . . $v''d''$ will be the elevation of the intersection.

To determine the shape of the end plate of the strut, make GG equal to its circumference and divide up in the same way as *erf* was divided and set up from GG to points D, V, etc., equal to the distances of d'', v'', etc., from the diameter *gh*. Then a curve through DV . . . V′D will give the development of the intersection.

(The shape D″V″W″ . . . D′ is the side elevation of the hole in the mast, and D″X‴ . . . D′ the expansion of this hole. These are simply obtained and require no explanation.)

A Vessel trims considerably by the Stern and has a list to Starboard. Show how to determine the True Shape of the Plane of Flotation.—Let Fig. 116 represent the sheer and body plan of the vessel with sections 1 to 5 shaped as shown, W_0L_0

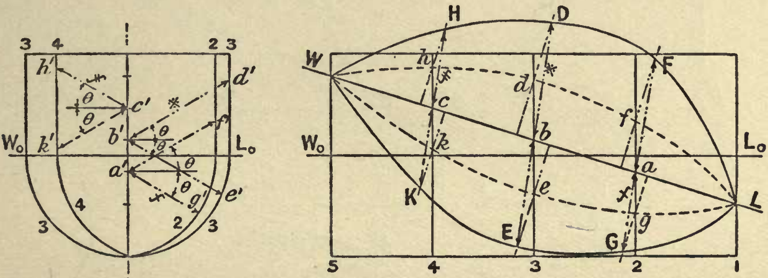


FIG. 116.

being the ordinary water-line. Let WL be the new water-line, and let the angle of inclination be θ. WL cuts the sheer sections in a, b, c, which are squared to the body at a', b', and c'. $b'd'$, $b'e'$, etc., are drawn at the required inclination cutting the sections in d', e', etc. $b'd'$ will be for the starboard side and $b'e'$ for the port side at section 3, and so on for other sections. The points as d', e', etc., are levelled across on to the sheer at d', e', etc. The curved lines W*hdf*L and W*kcg*L are the projections in the sheer plan of the edges of the inclined water-plane. Now imagine this water-plane rabatted on to the sheer about WL. Take the point whose projections are (d, d'). It will always move perpendicular to the axis of rebatment WL. Therefore draw dD perpendicular to WL. The actual length of the intersection of the water-plane with the section from the middle line is given by $b'd'$. Therefore make bD equal to $b'd'$, and D will be the edge of the water-plane at section 3 after rabatment. Other spots are obtained, as H and F, for the starboard side, and a curve drawn through WH . . . L gives the true shape for the starboard side, and WK . . . L for the port side.

(NOTE.—The line *b*D before rabatment was in the section No. 3, and not the line through *d*D. Hence *b*D is made equal to *b′d′* and not the square line through *d*D, this latter is a very common mistake.)

A large engine hatch is to be protected with 6-in. armour on the sides and ends. The side armour is at an angle of 45° to the horizontal, and the end armour is at 60°. Determine—

(i.) The shape of the moulds for a side and an end plate.

(ii.) The bevels to which the edges of the armour plates must be planed to ensure a good fit.

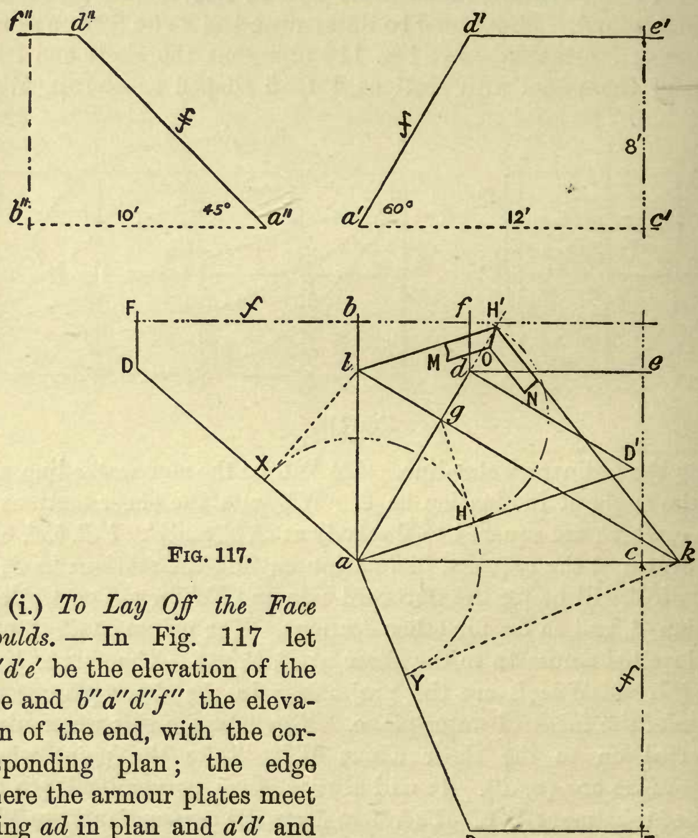


FIG. 117.

(i.) *To Lay Off the Face Moulds.* — In Fig. 117 let *c′a′d′e′* be the elevation of the side and *b″a″d″f″* the elevation of the end, with the corresponding plan; the edge where the armour plates meet being *ad* in plan and *a′d′* and *a″d″* in the two elevations.

Rabat the side about *ac* on to the HP., viz. *a*DE, *c*E being made equal to the slant length *a″d″*, and rabat the end about *ab* on to the HP., viz. *a*DF, *b*F being equal to the slant side *a′d′*.

To determine the Bevels.—The bevels of the lower and upper edges present no difficulty, being given by the angles $c'a'd'$ and $e'd'a'$ for the end plate and by the angles $b''a''d''$ and $f''d''a''$ for the side plate. For the angle between the plates along the edge (ad, $a'd'$) we use the method described in Chap. I. for determining the angle between two planes. The construction given in the figure results in the angle $lH'k$. The thickness of the armour is set in from lH' and kH', viz. MO and NO. The angles required for the bevels are $lH'O$ and $kH'O$, which, of course, are equal.

EXAMPLE.—Work out the above problem with the dimensions shown in figure, and state the angle of the bevel of each plate along the junction. Check the accuracy of your work by drawing lX and kY perpendicular to the two lines aD, and see if $aX = aY = aH$. Why must this be the case? *Ans.* 55 degrees.

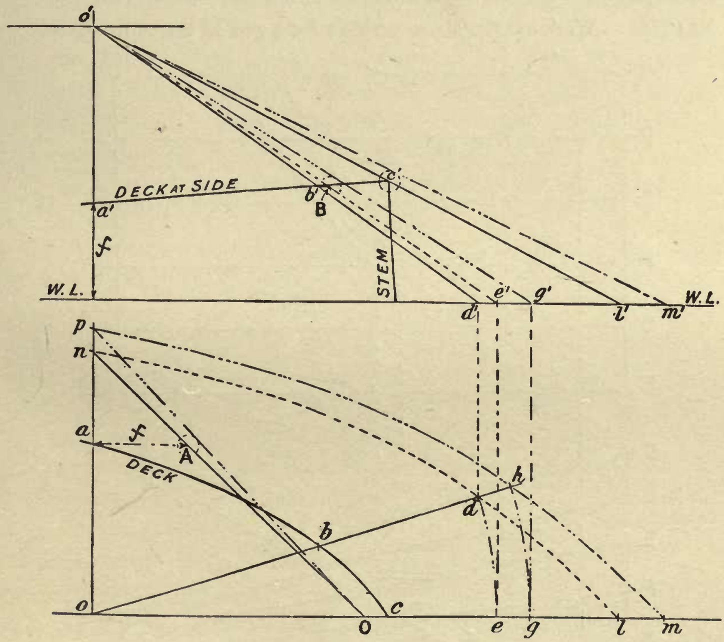


FIG. 118.

Determine the locus of the points where a shot will strike the water from a gun on the centre line supposing—

(i.) The clearance from the deck edge is given; and

(ii.) The trajectory of the shot is straight.

Let $a'b'c'$, Fig. 118, be the deck at side in the sheer, WL the water-line, abc the plan of deck, o' being the elevation of the centre of the gun. (The drawing is out of proportion for the sake of clearness.) We first find the locus of the points where rays from o' passing through the deck edge meet the water. This needs no description and results in the line *ndl*.

At c' and A draw circular arcs having for radius the radius of the shot plus the clearance required, and draw $o'm'$ and Op as tangents. Square m' down to m. Then p and m are points on the required locus. Take a line as *od* and rabat the vertical plane through *od* on to the vertical plane. Square e up to e' and join $o'e'$, and level b' along to meet $o'e'$ in B. With B as centre describe a circular arc with radius as above, and draw $o'g'$ as a tangent. Square g' down to g and sweep g round to h. Then h is a point in the locus required. Other points obtained in a similar manner will enable the line *phm* to be drawn, which is the locus required.

EXAMPLE.—Work out the above problem for a gun off the centre line.

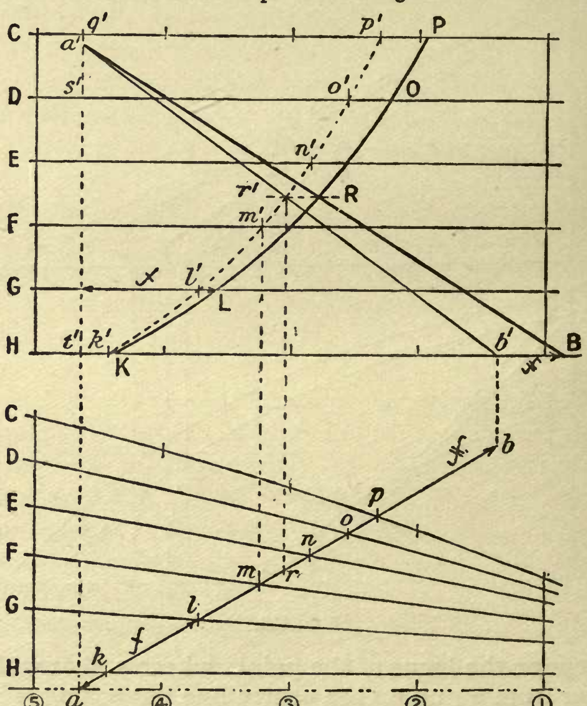


FIG. 119.

To find the Point where a given Straight Line will intersect the Surface of a Ship (Fig. 119).—Let the surface be defined by the level lines C, D . . . H, the stations being 1 to 5.

The given line is shown by its projections (ab, $a'b'$) with vertical trace (a, a') and horizontal trace (b, b'). ab meets the level lines in points k, l, etc., and these squared up to the sheer give points k', l', etc. A curve through k', l' . . . p' will be the vertical projection of the intersection of a vertical plane through the line (ab, $a'b'$) with the surface of the ship. The point r' where $a'b'$ meets this line will be the vertical projection of the intersection of the line (ab, $a'b'$) with the surface, and r' squared down to ab will give r the horizontal projection of this intersection. The point (r, r') is therefore the required intersection.

To find the true shape of the curve of intersection we rabat the vertical plane through (ab, $a'b'$), about $t'a'$ on to the sheer. Make $q'\text{P} = ap$, $s'\text{O} = ao$, $t'\text{K} = ak$, and similarly for other points, and draw a curve through PO . . . K, which will be the true shape required. The horizontal trace of (ab, $a'b'$) by this rabatment will go to B where $t'\text{B} = ab$, and K where a'B meets the curve PO . . . K will be intersection of the line with the surface as rabatted. a'R will be the true length of the line from (a, a') to the intersection. (r' and R will, of course, be in the same horizontal.)

To determine the Intersection of a Cylinder with the Surface and Deck of a Ship.—(This is the problem of the hawse pipe and an extension of the previous problem.)

Fig. 120 shows the half-breadth and sheer (the round of deck is much exaggerated for the sake of clearness). Let (ab, $a'b'$) be the centre line of the cylinder. Draw a horizontal diameter (4, 10) and the sides of the cylinder through 4 and 10 in plan. On (4, 10) describe a semicircle, which divide into equal parts at 11, 12, 1, 2, etc., and project these points back to (4, 10) at k, h, g, f, etc. Vertical planes passed through the points 4, e, . . . k, 10, will cut the cylinder in equidistant generators numbered 1 to 12, of which No. 5 will be immediately under No. 3, No. 6 under No. 2, and so on. Determine the projections of these generators 1 to 12 in elevation at 1′ to 12′ by the problem on page 13.

The vertical planes cut the ship's surface in lines, the projections of which, in elevation, are found by squaring the intersections of the planes with level lines in plan, up to the sheer. Thus l to l', m to m', n to n', on 4 waterline, and so on. In this way the curves C′, D′, E′, etc., are drawn. Intersections are then picked out, thus 10 generator meets ship's side at p, 1 at q', 7 at r', etc. In this way the elevation of the curve in which the cylinder cuts the side can be drawn as dotted. The horizontal projection is obtained by squaring down, as shown, *e.g.* r' on 7 generator, to r.

The vertical planes also cut the deck in curves the projections of which are readily obtained by using a series of bow lines as A, B, C. Thus s to s' is a specimen point on bow line B. Corresponding points are picked out as before and the vertical projection of the intersection with the deck drawn in as dotted. The horizontal projection is again found by squaring down as shown.

To determine the True Shape of the Hole made in the Side of a Ship by a Cylindrical Hawse Pipe.—(Strictly speaking this is not possible, as the surface of a ship is not a developable surface, but the solution given below gives a close approximation.)

Find the true shape of the intersection of the cant planes C, D, etc., with the surface. This is given in Fig. 120 (a) by determining distances from XY and setting off from X′Y′ in the new elevation, thus obtaining an elevation in the direction of the arrow, and obtaining the curves C″, D″, etc., as the true shapes of the intersections. All corresponding points are at the same level, which will enable the projection of the intersection of the cylinder with the side to be readily determined. It is observed that girths along these cants are *true lengths,* thus $w''x''$ is the true distance of the edge of the hole from No. 4 WL measured along the cant. Also *true lengths* along a W.L. are obtained from the half-breadth. This is the principle adopted in obtaining the development. Draw Y″Z″ perpendicular to the general run of the cants C″, D″, etc., and develop this at Y‴Z‴ in the lower figure. It is assumed that this develops into a straight line, and the cants come at C‴D‴, etc. Draw the middle cant as straight at O‴. Girth each cant from Y″Z″ to the respective water-lines and set out from Y‴Z‴ by short lines as shown. Find the lengths along the water-lines in the half-breadth and set off as shown for the point W‴. This will enable the developed water-lines to be run in, and also the developed cants. Points for the intersection of the cylinder with the side can then be found, as W‴x''' down from No. 4 water-line is equal to $w''x''$, and similarly along the developed water-lines, the distances as found from the half-breadth. Corresponding distances are shown in the figure, and the developed shape of the intersection may then be drawn in. The hole in the deck may be developed in a similar manner by completing the top part of the figure (a).

The development of the surface of the cylinder intercepted between the deck and the side can be obtained on the principle of the mast development already described.

EXAMPLE.—Work out the above for a conical hawse pipe.

The above examples are most interesting and instructive, and every student is advised to take such a fair surface as in Fig. 120

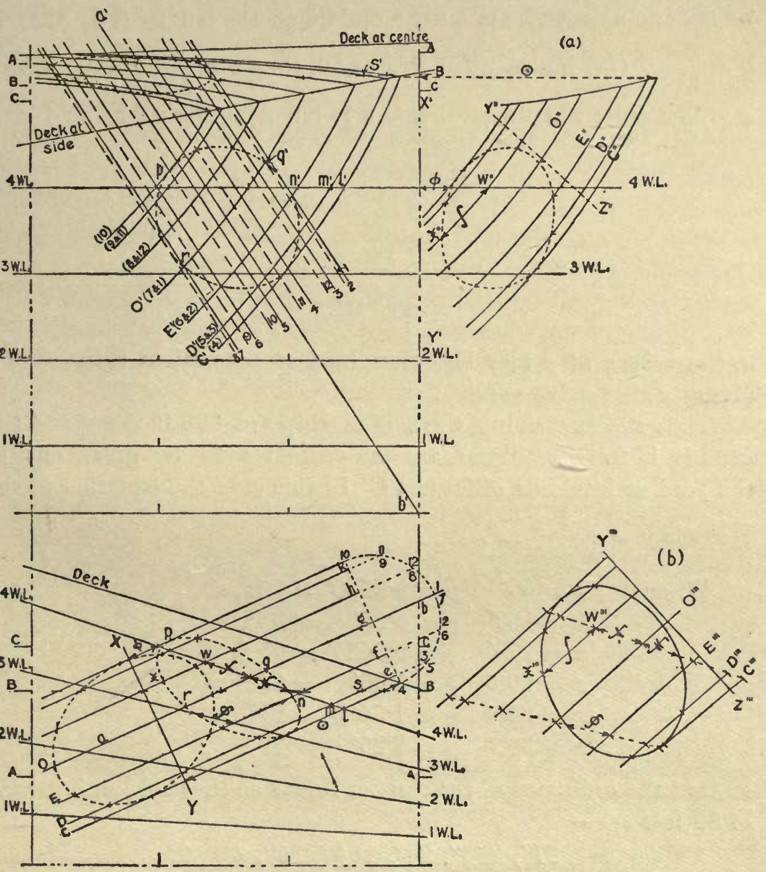


FIG. 120.

and to draw out the solutions himself. It will be noticed that a simple fair surface is obtained by using straight water-lines and straight deck at centre with an exaggerated round of beam.

To determine the Curve of Launching Ways having Camber.—Launching ways for heavy ships are usually given a camber, and in order to avoid straining the ship as she goes down the ways, it is essential that the curve of the ways should be a true circular arc. The arc is so flat that it is not practicable to draw it out so that measurements can be taken with proper accuracy, so it is necessary to use the equation to the curve.

The curve is practically that of a parabola, and if 2L be the length for which the camber is a (both in feet, say) the equation referred to axes OX, OY at the middle of the length (Fig. 121) is $y = \frac{a}{L^2} . x^2$ (*i.e.* if at a point P, $x = 50$, then $y = \frac{a}{L^2} . 2500$. When $x = 0, y = 0$; when $x = L$, $y = a$.) Knowing the values of L and

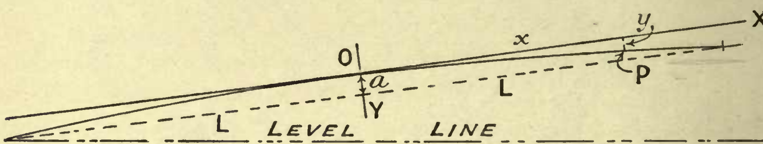


FIG. 121.

a, the values of y may be determined at convenient intervals by giving x successive values.

Thus the launching ways of a ship are 600 ft. long and the camber is 27 in. What are the ordinates to be given out to the yard at intervals of 50 feet? In this case the equation to the curve is $y = \frac{1}{40,000} . x^2$.

When	$x = 50'$	$y = 0{\cdot}0625'$	$= \frac{3}{4}$ in.
	$x = 100'$	$y = 0{\cdot}25'$	$= 3$ in.
	$x = 150'$	$y = 0{\cdot}5625'$	$= 6\frac{3}{4}$ in.
	$x = 200'$	$y = 1{\cdot}00'$	$= 12$ in.
	$x = 250'$	$y = 1{\cdot}5625'$	$= 18\frac{3}{4}$ in.
	$x = 300'$	$y = 2{\cdot}25'$	$= 27$ in.

so that the ordinates of the camber line from the chord at intervals of 50 feet are—

$$27'', 26\tfrac{1}{4}'', 24'', 20\tfrac{1}{4}'', 15'', 8\tfrac{1}{4}'', 0.$$

EXAMPLE.—The groundways of a vessel are 500 ft. long, and in this length the camber is to be 24 in. Determine the heights from the chord at intervals of 50 ft. *Ans.* $24''$, $23\frac{1}{16}''$, $20\frac{1}{8}''$, $15\frac{3}{8}''$, $8\frac{5}{8}''$, 0.

APPENDIX

BOARD OF EDUCATION EXAMINATION IN NAVAL ARCHITECTURE. SYLLABUS OF THE PORTION RELATING TO LAYING OFF.

Lower Examination.—A knowledge of the work carried on in the mould loft for the purpose of fairing a set of lines, including traces of keelsons and longitudinals, edges of shell plating, tank margins, ribbands, etc., and transferring the frame and other lines to the scrive board; lifting the bevels and constructing round of beam mould; a ship's block model, and the information necessary for its construction; obtaining the dimensions for ordering the shell plating, frames, beams, floors, inner bottom plating, etc.; making and marking ribbands; fairing the edges of shell plating on the frames; making templates or skeleton patterns for stem, stern-post, propeller brackets, forgings, or castings.

Higher Examination.—Expanding the plating of longitudinals and margin plates by the geometric and mocking up methods; expanding stern plating, rudder trunking, and mast plating; obtaining the true shape of a hawse hole in the deck or shell, and similar practical problems; constructing and fairing the form of a twin-screw bossing.

SPECIMEN EXAMINATION QUESTIONS IN LAYING OFF.

(1) Final Examination at the Royal Naval College, Greenwich.

What is a scrive board, and what lines are usually transferred to it from the mould loft floor? State what moulds would be supplied from the mould loft for a ship for which a scrive board has been prepared.

A ship has considerable trim by the stern and a list to starboard. Show how to determine the true shape of the plane of flotation.

Describe the process of laying off and obtaining the bevelling of a harpin. Give a sketch of a hairpin mould, showing the marks usually placed on it.

How would you lay off and obtain the bevellings of an ordinary cant? Why are cant frames rarely used in warships?

How would you determine the position and length of a bilge keel for a steel ship in the body and sheer plans? Describe the method of getting in "at the ship" the lines for a bilge keel, and state what information would be supplied from the mould loft for this purpose.

Describe the method adopted for laying off a longitudinal in the double bottom—

(*a*) Where there is little twist;

(*b*) Where considerable twist occurs.

Describe in detail the information supplied from the mould loft in both these cases.

Explain, with sketches, how you would obtain and fair on the mould loft floor the parts of the transverse frames in way of the screw shafts.

What information would be supplied from the mould loft for preparing these frames?

The building drawings of a new ship having been received at a dockyard, describe generally the steps which would be taken in the mould loft and drawing office, and the order in which they would be taken with a view of laying down the ship as soon as possible.

Sketch roughly a complete set of moulds for a transverse frame of a large warship, showing the marks that are placed upon them.

What is meant by (*a*) moulded breadth and depth, (*b*) length between perpendiculars?

In working out a "displacement sheet" from the lines on the mould loft floor, how would you make allowance for the bottom plating?

Describe how to obtain the true form of the intersection of a ship's surface with the plane of a double cant frame.

A submerged torpedo tube is fitted athwartships near the stern at 3 degrees depression. Show how to obtain the true form of the intersection with the side of the vessel.

Armoured protection is to be fitted over a portion of the engine-room, between the protective deck and deck above. The sides and ends slope at 45°. The sides of the protection are straight in plan, but inclined to the middle line. Assuming the protective deck to have round up and no sheer, and the deck above round up and sheer, show how to obtain the true shape of the armour plates.

Show how you would obtain the true shapes of the intersections between the mast and the legs of a tripod mast.

Describe how the lines for the inner bottom plating are obtained and faired on the mould loft floor.

Describe the half-block model used on the mould loft floor for a ship building. State what information is shown on it, how this information is obtained, and what use is made of it.

Explain how to find the intersection of a main engine discharge pipe with the outer bottom, assuming the pipe to be conical and with its axis *not* parallel to either sheer, half-breadth or body plans.

A tripod mast stands on a deck having considerable round up and sheer. How would you obtain the true shapes of the lower plates of tripod legs, and the bevels of the deck connecting angle bar?

Describe the information which would be furnished to the Contractors for the shaft brackets of a large ship. How is this information obtained?

Describe the construction of a modern mould loft floor, and the various tools and appliances necessary for laying off.

Sketch and describe a bevelling frame, and state how the information is obtained and prepared for yard use of—

(*a*) Ordinary transverse framing;

(*b*) Angles connecting longitudinals to frames;

(*c*) The lower boundary angle of a vertical fore and aft bulkhead inclined to the middle-line plane, where the bottom has considerable curvature both fore and aft and athwartships.

Lay off the stringer plating of a deck having both round up and sheer.

(2) *The following are from the Board of Education Examination*, 1913.

What is a scrive board? Sketch the scrive board for a vessel, and state what information is placed upon it to enable the vessel to be built to required form.

What moulds would be issued from the mould loft floor for the ship for which such a scrive board is prepared?

Explain how edges of outer bottom plating and longitudinals are obtained and faired on the mould loft floor.

The frames at the fore end of a ship are to be arranged to lie in planes square to the middle-line plane, but inclined to the vertical. Explain how you would lay off and obtain bevellings for one of these frames.

Point out the resemblances and the differences between this problem and the laying off of an ordinary cant frame.

Miscellaneous Questions.

1. A large wooden beam is to be fitted obliquely across the underside of a deck which has round and sheer. Show how to obtain the shape of the beam and the bevellings. The sides of the beam are parallel and vertical.

2. Show how to determine the expanded shape and bevels of a deck boundary bar where there is considerable round and sheer.

3. An oblique fore and aft bulkhead cuts the knuckle of the protective deck. The slope of the deck is 45°, and the deck at side is a level line in the body plan. Show how to determine the shape and bevels of a boundary bar for the top of the bulkhead.

4. A sea inlet is fitted with a conical steel pipe between the inner and outer bottoms. Show how to develop the surface of the pipe.

5. Show how to obtain the shape of a cant frame by using bow lines; describe how the bevelling would be obtained.

6. Explain with sketches the principle and use of a bevelling frame.

7. How would you determine the shape of a doubling plate on a mast which has rake and taper?

8. A deck house is built of thin plating, with vertical sides and corners bent to 12 in. radius. The deck on which it stands, and also the deck above, have round up and sheer: show how to develop the plating.

9. Having given the lines of a sheathed ship to the outside of planking, show how to find and how to end the frame lines.

10. What points have to be considered in fixing the position of a bilge keel for a new ship? Illustrate by sketch the shape of the bilge keel in the three plans.

11. Develop the surfaces and find the bevels of the plates of an armoured turret.

12. A large ventilation trunk is square in section where it passes through one deck and circular where it passes through the deck immediately above it. The trunk is made up of four plates of equal size jointed from the corners of the square section at the bottom to equidistant points on the circumference of the top. Show how to find the shape of one of the plates.

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THE END

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